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(54) Method for producing liquid discharge head, liquid discharge head, head cartridge, liquid discharging recording apparatus, method for producing silicon plate and silicon plate

Verfahren zur Herstellung eines Flüssigkeitsausstosskopfes, damit hergestellter Flüssigkeitsausstosskopf, Kopfkassette, Flüssigkeitsausstossvorrichtung, Verfahren zur Herstellung einer Siliziumplatte und damit hergestellte Siliziumplatte

Procédé de production d'une tête à éjection de liquide, tête à éjection de liquide ainsi produite, cartouche, appareil d'éjection de liquide, procédé de production d'une plaque de silicium et plaque de silicium ainsi produite

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a method for collectively producing plural silicon plates by forming plural functional units on a silicon wafer and dividing the silicon wafer for each functional unit. Said functional unit can be used as an orifice plate for producing a liquid discharge head, applicable to a printer for recording on recording media.

Related Background Art

[0002] For improving dot placement accuracy of the liquid droplet by an ink jet head which is a liquid discharge head, there has conventionally employed a tapered orifice which is thicker in the base portion at the liquid chamber side and thinner in the front end portion at the discharge port side, with a cross section gradually decreasing toward the front end portion. For forming such tapered orifice on an orifice plate, there has been employed, for example, electroforming on a nickel sheet, hole formation on a resin sheet with an excimer laser and hole formation on a stainless steel sheet by pressing.

[0003] Also the European Patent Laid-Open No EP-A-0921004 discloses the use of silicon (Si) for the orifice plate of the ink jet head. The specification of this patent describes formation of an orifice plate consisting of silicon and having discharge orifices, by grinding a silicon plate in which penetrating holes are formed into a thickness of 10 to 150 μm. For forming such discharge orifices, there are described a method of ion beam working (in vacuum), excimer laser working and etching (dry etching or wet etching).

[0004] Also for silicon material, the U. S. Patent No. 5,498,312 discloses a technology of executing plasma etching introducing a mixture of etching gas such as SF_6, CF_4 or NF_3 and passivating gas such as CHF_3, C_2F_4, C_2F_6, $C_2H_2F_2$ or C_4H_8 into a chamber and employing a plasma density of 10^{12} ion/cm^3 or higher and an energy range of 1 to 4 eV in order to increase the etching rate and avoiding the drawback of masking.

[0005] However, the above-described method for producing the orifice plate for the ink jet head utilizing silicon, disclosed in the aforementioned European Patent Laid-Open No EP-A-0921004 involves a step of preparing a silicon plate thicker than the predetermined thickness of the orifice plate and penetrating such silicon plate, and is therefore relatively time-consuming, so that there is still a room for the improvement in the mass producivility.

[0006] Also in case of etching of the silicon plate with the method described in the aforementioned U. S. Patent No. 5,498,312, the depth of the etched hole is little controllable and the fluctuation in the etched depth, resulting from the fluctuation in the material constituting the silicon plate, cannot be controlled, so that it is difficult to form the holes with satisfactory precision.

[0007] US 5,071,792 discloses a wafer processing technique that separates an extremely thin wafer into a plurality of completed circuit-containing dice without having to directly handle the wafer. A substrate is thinned by forming a trench pattern in its top surface, the trench depth being the intended thickness of the die. A polishing resistant material is then formed in the trench and planarised down to a topside passivating layer, which is patterned to expose surface test regions. The substrate is backside-lapped down to the stop material in the trench, leaving a thin wafer layer. After the trench material is removed, individual dice are separated from the support handle.

SUMMARY OF THE INVENTION

[0008] In consideration of the foregoing, a principal object of the present invention is to provide a novel method excellent in mass producibility capable of forming penetrating holes of a uniform shape in plural units at the same time, without being affected by the fluctuation in the crystal structure of silicon.

[0009] The principal features of the present invention, for attaining the above-mentioned object, are as follows.

[0010] The present invention provides a method for collectively producing plural silicon plates by forming plural functional units on a silicon wafer and dividing the silicon wafer for each functional unit. The method comprises a step of forming, by dry etching, a plate dividing pattern corresponding to an external shape of each silicon plate on a first surface of the silicon wafer; a step of dividing the silicon wafer by thinning the silicon wafer from a reverse surface opposite to the first surface at least to the plate dividing pattern; and a step of providing each silicon plate with a through hole, wherein a through hole formation portion and the plate dividing pattern are simultaneously etched during the step of dry etching.

[0011] It is preferred that the step of thinning the silicon wafer is executed by reducing the thickness of the silicon wafer from the reverse surface thereof by a process selected from the group consisting of grinding, polishing, and etching.

[0012] Moreover it is preferred that the producing method further comprises, before the step of dividing the silicon wafer, a step of providing a tape on the surface of the silicon wafer, in order to maintain the strength of the silicon wafer during any subsequent grinding or polishing thereof.

[0013] Furthermore it is preferred that the producing method further comprises, after the step of dividing the silicon wafer, a step of peeling off the tape.

[0014] Moreover it is preferred that the producing method further comprises, after the step of dividing the silicon wafer, a step of conveying the silicon plate.

[0015] Furthermore it is preferred that in the producing method the silicon plate is stored during the step of con-

veying the silicon plate.

[0016] Moreover it is preferred that in the producing method the plate dividing pattern is formed excluding an external periphery of the wafer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

Fig. 1 is a perspective view showing a liquid discharge head comprising a silicon plate;

Fig. 2 is a cross-sectional view of the liquid discharge head shown in Fig. 1, along the liquid flow path thereof;

Fig. 3 is a perspective view showing the assembling the liquid discharge head shown in Figs. 1 and 2;

Figs. 4A1, 4A2, 4B, 4C1, 4C2, 4D1, 4D2, 4E1 and 4E2 are views showing details of a method for producing a particular orifice plate shown in Figs. 1 and 2;

Fig. 5 is a perspective view showing another liquid discharge head comprising a silicon plate;

Fig. 6 is a cross-sectional view of the liquid discharge head shown in Fig. 5, along the liquid flow path thereof;

Fig. 7 is a perspective view showing the assembling of the liquid discharge head shown in Figs. 5 and 6;

Figs. 8A1, 8A2, 8B, 8C1, 8C2, 8D1, 8D2, 8E1 and 8E2 are views showing details of a method for producing a particular orifice plate shown in Figs. 5 and 6;

Figs. 9A, 9B, 9C, 9D, 9E, 9F and 9G are views showing a method for producing a liquid discharge head.

Fig. 10 is a flow chart showing the preparation process for the orifice plate, to be explained with reference to Figs. 9A, 9B, 9C, 9D, 9E, 9F and 9G;

Fig. 11 is a perspective view showing a liquid discharge head, constituted by adhering four head main bodies to an adjoined member of an orifice plate and a frame member;

Figs. 12A1, 12A2, 12B, 12C1, 12C2, 12D, 12E1, 12E2, 12F, 12G1 and 12G2 are views showing detailed steps for preparing an orifice plate of the liquid discharge head, in the method for producing the liquid discharge head;

Fig. 13 is a perspective view showing the assembling of the liquid discharge head, employing the orifice plate prepared by the steps shown in Figs. 12A1, 12A2, 12B, 12C1, 12C2, 12D, 12E1, 12E2, 12F, 12G1 and 12G2;

Figs. 1-4A1, 14A2, 14B1 and 14B2 are views showing a variation of the method for producing the orifice plate shown in Figs. 12A1, 12A2, 12B, 12C1, 12C2, 12D, 12E1, 12E2, 12F, 12G1 and 12G2;

Fig. 15 is a perspective view showing an ink jet recording apparatus, constituting an example of the liquid discharge recording apparatus equipped with the liquid discharge head comprising a silicon plate;

Figs. 16A, 16B, 16C and 16D are cross sectional views showing the flow of the producing process, particularly in relation to the shape of the port formed in the orifice plate in the process steps shown in Figs. 4A1, 4A2, 4B, 4C1, 4C2, 4D1, 4D2, 4E1 and 4E2;

Figs. 17A, 17B and 17C are cross-sectional views showing a variation of the producing method of the orifice plate explained in relation to Figs. 4A1, 4A2, 4B, 4C1, 4C2, 4D1, 4D2, 4E1 and 4E2;

Fig. 18 is a flow chart of producing steps of an orifice plate;

Figs. 19A, 19B, 19C, 19D, 19E, 19F, 19G, 19H and 19I are views showing details of another method for producing a particular orifice plate;

Fig. 20 is a view showing a plate dividing pattern in a producing method of plural silicon plates according to the present invention;

Figs. 21A, 218, 21C and 21D are views showing a method for producing the orifice plate in which applied is the producing method of plural silicon plates according to the present invention;

Figs. 22A, 22B, 22C and 22D are views showing the conveying of a silicon wafer in the producing method of the orifice plate explained in relation to Figs. 21A, 21B, 21C and 21D;

Fig. 23 is a view showing the conveying of the silicon wafer in the producing method of the orifice plate explained in relation to Figs. 21A, 21B, 21C and 21D; and

Figs. 24A, 24B and 24C are views showing a variation of the conveying of the silicon wafer in the producing method of the orifice plate explained in relation to Figs. 22A, 228, 22C, 22D and 23.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] In the following, the present invention will be clarified in detail by embodiment thereof, with reference to the accompanying drawings.

[0019] Figs. 20 and 21A to 21D are views showing a method for producing plural silicon plates according to the present invention.

[0020] The present embodiment uses a silicon wafer 301 as the silicon substrate and a plate dividing pattern 301b formed excluding an external periphery portion of the silicon wafer 301 (cf. Fig. 20).

[0021] The present embodiment utilizes, in dividing the silicon wafer 301, so-called "prior dicing" method disclosed in the Japanese Patent Application Laid-Open No. 9-213662. The "prior dicing" method consists of forming grooves, along grid-patterned dicing lines positioned on a wafer bearing semiconductor elements, by a dicing operation from the surface bearing the semiconductor elements to a predetermined depth, then adhering a back grinding tape on the surface, bearing the semiconductor elements, of the wafer and grinding and polishing the reverse surface of the wafer until such grooves are

reached, thereby dividing the wafer into the individual chips.

[0022] The present embodiment is same as the "prior dicing" process in that the plate dividing pattern (grooves) is formed on the wafer and in that the wafer is divided by grinding from the reverse surface thereof after the formation of the plate dividing pattern. Also the adhesion of the back grinding tape on the surface bearing the plate dividing pattern is similar to the adhesion of the UV peelable tape in the present embodiment, for maintaining the strength of the wafer.

[0023] In the "prior dicing" process, however, since the plate dividing pattern is formed by dicing, the grooves are formed to the external periphery of the wafer. On the other hand, the external peripheral area of 2 to 5 mm of a silicon wafer is outside the effective area thereof, and is an area in which the wafer has a smaller thickness and is not used for forming patterns. Consequently the divided silicon in such external peripheral portion is only weakly supported by the back grinding tape and may result in chip cracking to damage other satisfactory chips. Also after the thinning operation of the wafer, the orifice plates (chips) are supported only by the sheet, so that the wafer is lowered in rigidity and is bent in the conveying or in insertion into a cassette, thereby eventually leading to a trouble in conveying operation or a cracking by collision. Besides, the external shape of the orifice plate is limited because the dicing operation can only provide linear plate dividing pattern.

[0024] The present embodiment is to provide means for resolving such drawbacks in the "prior dicing" process. The present embodiment is different from the "prior dicing" process in that the plate dividing pattern is formed by etching and that the plate dividing pattern is not formed in the external periphery portion of the wafer, thereby resolving the drawbacks in the "prior dicing" process. More specifically, in the present embodiment, the plate dividing pattern, being formed by dry etching, can be formed in an arbitrary manner, providing a larger freedom in the external shape of, e.g. an orifice plate. Also because the plate dividing pattern is formed by dry etching, the external periphery portion of the wafer can be left free of the plate dividing pattern, whereby the external periphery portion may be maintained intact after the thinning operation. Therefore, in the grinding and polishing operations, the external periphery portion of the wafer can be protected and can be prevented from fluctuation in the thickness resulting from a decrease in the thickness therein, or chipping or cracking of the orifice plate in the external periphery poriton as encountered in the "prior dicing" process, whereby the dimentional precision and production yield can be improved. Also since the external periphery portion remains after the thinning operation, the wafer is supported by such external periphery portion and the UV peelable tape. Thus the wafer after the thinning operaiton has a higher rigidity and shows a smaller bending in the conveying of wafer or the insertion thereof into the cassette, thereby preventing troubles in conveying or cracks by collision. Furthermore, the dry etching can collectively form the recesses constituting, e.g. discharge ports after the thinning operation and the plate dividing pattern, thereby reducing the number of steps and the manufacturing cost.

[0025] In the following the present embodiment will be explained with reference to the accompanying drawings.

[0026] At first there is prepared a silicon substrate 301 of a thickness of 625 μm as shown in Fig. 21A, and, on the surface of the silicon substrate 301, an Al layer is formed with a thickness of 8 μm by sputtering.

[0027] Then, on the Al layer on the silicon substrate 301, a resist material is coated with a thickness of 8 μm and is patterned in order to form, on the silicon substrate 301, discharge ports 3 and a groove-shaped plate dividing pattern 301b for dividing the silicon substrate 301 into the individual chips. The resist was composed of Shipley SJR-5740, was coated with a coating apparatus CDS-600 supplied by Canon Inc. and was patterned by an exposure apparatus MPA-600 supplied by Canon Inc. The exposure amount was 1 J/cm^2 and the development was executed with exclusive developer.

[0028] Then the patterned resist is used as a mask to dry etch the Al layer on the silicon substrate 301, thereby forming therein an etching mask Al layer bearing a pattern of openings in positions corresponding to the discharge ports 3 on the silicon substrate 301 as shown in Fig. 21A. This dry etching also forms, on the Al layer, grooves for dividing the silicon substrate 301, corresponding to the groove-shaped plate dividing pattern 301b. The dry etching was conducted with chlorine gas and a dry etching apparatus NLD-800 supplied by Alvac Co. The Al layer was etched in such dry etching apparatus, with a power of 1000 W, a bias of 100 W and a pressure of 0.8 Pa.

[0029] Then the resist on the Al layer is removed by ashing.

[0030] Then the Al layer is used as a mask to deep etch exposed portions of the silicon substrate 301 at the side of the Al layer by dry etching ions 23 thereby forming recessed holes 301a in plural units with a depth of 70 + 5 to 50 μm in positions corresponding to the discharge ports 303 and a groove-shaped plate dividing pattern 301b for dividing the silicon substrate 301 into plural orifice plate, on the surface of the silicon substrate 301, as shown in Fig. 21A. The etching gas was composed of C_3F_8 mixed with oxygen of 5 vol.%, and the dry etching was conducted with a power of 1000 W, a bias of 150 W and a gas pressure of 5 Pa. The depth of the plate dividing pattern 301b is 70 + 5 to 50 μm as in the case of the holes 301a. Thus there is formed, on the surface of the silicon substrate 301, a pattern including the plate dividing pattern 301b and the plural holes 301a. The plate dividing pattern 301b is formed excluding the external peripheral portion of the silicon wafer 301, as shown in Figs. 20 and 21A to 21D.

[0031] The mask in the above-explained step was composed of the Al layer, but a SiO_2 layer may be used instead as explained with reference to Figs. 17A to 17C

later. Thus the plate dividing pattern 301b and the plural holes 301a are formed and an SiN protective film 26 is formed with a thickness of 2 μm by CVD through a process similar to that explained with reference to Figs. 16A to 16D or 17A to 17C.

[0032] Then, as shown in Fig. 21B, the surface of the silicon substrate 301 at the side of the holes 301a is adhered to a UV peelable 304, and the reverse surface of the silicon substrate 301 is grond and polished to thin the silicon substrate 301 to a thickness of 50 μm. In this operation, the silicon substrate 301 is adhered to the UV peelable tape 304, which is a back-grinding tape for maintaining, to a certain extent, the strength of the silicon substrate 301 in the grinding/polishing operation thereof. The back grinding tape is generally composed of a polyolefin base film and an acrylic adhesive coated thereon, in which the acrylic adhesive is either a UV peelable type or a UV insensitive type. The UV peelable type, having a strong chip supporting power at the back grinding operation and showing a decrease in the adhesive power by the subsequent UV irradiation, provides an advantage that the chips can be easily picked up. The present embodiment employed such tyep FS-3323-330 supplied by Furukawa Denko Co. The thickness of the UV peelable tape 304 is preferably about 200 μm, since an excessively small thickness results dificient rigidity, incapable of sufficiently supporting the wafer 304 after the thinning operation, thus eventually leading to troubles in the wafer conveying operation, while an excessively large thickness results in insufficient UV irradiation for peeling.

[0033] The grinding operation of the reverse surface of the silicon wafer 301 causes, as shown in Fig. 21C, the bottom of each hole 21a to open in the reverse surface of the silicon wafer 301 to form a penetrating hole, whereby the discharge ports 3 are formed in the silicon wafer 301 and the silicon wafer 301 is divided into plural orifice plates 316 according to the plate dividing pattern 301b. The thinning of the silicon wafer 301 may also be achieved by etching the reverse surface thereof.

[0034] Finally, the UV peelable tape 304 is peeled off by UV irradiation as shown in Fig. 21D, whereby the wafer is collectively separated into the plural orifice plates 316. The UV irradiation was conducted with an apparatus UVM-200 supplied by Furukawa Denko Co., with an irradiation amount of 2 J/cm^2.

[0035] Through the above-described process, there are collectively produced orifice plates 316, prepared by forming the discharge ports 3 in the silicon wafer 301, as shown in Fig. 21D.

[0036] In the following there will be explained a step of conveying the silicon wafer 301 after the dividing step thereof.

[0037] After the silicon wafer 301 is divided by thinning on a stage 321 with a vacuum chuck as shown in Fig. 22A, the vacuum of the stage is terminated and the push-up pins are elevated to lift the silicon wafer with the UV peelable tape 304, as shown in Fig. 22B.

[0038] Then a robot arm 322 as shown in Fig. 22C is activated to transfer the silicon wafer with the UV peelable tape 304 to a casette tray as shown in Fig. 22D, whereby the silicon wafer with the UV peelable tape 304 is housed in a cassette tray 324 as shown in Fig. 23.

[0039] The transfer of the silicon wafer 301 with the UV peelable tape 304 to the cassette tray 324 may also be executed by a process to be explained in the following with reference to Figs. 24A to 24C.

[0040] Figs. 24A to 24C show other steps of conveying the silicon wafer 301 with the UV peelable tape 304 to the cassette tray 324.

[0041] After the thinning of the silicon wafer 301 on a stage 321 with a vacuum chuck as shown in Fig. 24A, the vacuum of the stage is terminated and the silicon wafer 301 with the UV peelable tape 304 is sucked from the wafer side by a robot arm 323 with a vacuum chuck, as shown in Fig. 24B.

[0042] Then the sucked silicon wafer 301 with the UV peelable tape 304 is conveyed to a cassette tray 324 as shown in Fig. 24D, whereby the silicon wafer 301 with the UV peelable tape 304 is housed in the cassette tray 324 as shown in Fig. 23.

[0043] The silicon wafer 301 with the UV peelable tape 304 housed in the cassette tray 324 may be stored in a process state for conveying the silicon wafer 301.

[0044] The above-described producing method for e.g. an orifice plate in the embodiment is not limited to the preparation of an orifice plate but is likewise applicable for producing a silicon plate such as a semiconductor chip. In the application for producing a semiconductor chip, the plate dividing pattern, being formed by dry etching, can be formed in an arbitrary manner, providing a larger freedom in the external shape of the semiconductor chip. Also because the plate dividing pattern is formed by dry etching, the external periphery portion of the wafer can be left free of the plate dividing pattern, whereby the external periphery portion may be maintained intact after the thinning operation. Therefore, in the grinding and polishing operations, the external periphery portion of the wafer can be protected and can be prevented from fluctuation in the thickness resulting from a decrease in the thickness therein, or chipping or cracking of the orifice plate in the external periphery portion as encountered in the "prior dicing" process, whereby the dimensional precision and production yield can be improved. Also since the external periphery portion remains after the thinning operation, the wafer is supported by such external periphery portion and the UV peelable tape. Thus the wafer after the thinning operation has a higher rigidity and shows a smaller bending in the conveying of wafer or the insertion thereof into the cassette as explained in relation to Figs. 3A to 3D through, 5A to 5C, thereby preventing troubles in conveying or cracks by collision. Therefore the drawbacks in the "prior dicing" process can be resolved.

[0045] The silicon plate explained in the foregoing embodiment and the producing method therefor can be applied to a filter for preventing dust intrusion in liquid and

a producing method therefor. Such filter is to prevent intrusion of dusts larger than penetrating holes formed in the filter. According to the present invention, an alkali-resistant film is formed on the filter surface and in the interior of the penetrating holes, so that the filter can be used in stable manner even in liquid which attacks silicon. Also a water-repellent film is formed on the filter surface thereby increasing the hydrophilicity in the interior of the penetrating holes than on the filter surface, thereby realizing efficient liquid flow in the penetrating holes. Also the protective film in the interior of the penetrating holes is made to protrude to form projections, whereby, in a step of coating a water-repellent agent on the filter surface for forming a water-repellent film thereon, the water-repellent agent can be easily coated on the filter surface without intrusion into the interior of the penetrating holes.

[0046] Fig. 1 is a perspective view showing a liquid discharge head comprising a silicon plate, and Fig. 2 is a cross-sectional view of the liquid discharge head shown in Fig. 1, along the liquid flow path. As explained above the producing method for the liquid discharge head is attained, in employing silicon as the material of the orifice plate constituting the liquid discharge head, by the development of elementary technologies including etching, thinning and assembling technologies of silicon.

[0047] The liquid discharge head is composed, as shown in Fig. 1, of a head main body 7 by adjoining a top plate 15 to the surface of an element substrate 11, an orifice plate 16 adjoined to the front end face of the head main body 7 etc. The element substrate (hereinafter also called heater board) 11 is provided with plural energy generation elements (hereinafter also called heaters) 12 for generating thermal energy to be utilized for discharging liquid such as ink, and A1 wirings for supplying the energy generation elements 12 with electric signals. The element substrate 11 is prepared by forming, on a Si substrate, the plural energy generation elements 12 and the A1 wirings mentioned above.

[0048] On the surface of the element substrate 11, there are formed grooves for forming plural liquid flow paths 1 in which the energy generation elements 12 are respectively provided, and a groove for forming a liquid chamber 2 for temporarily containing ink to be supplied to the respective liquid flow paths 1. The two adjacent liquid flow paths 1 are partitioned by a liquid flow path wall 8 positioned therebetween. The grooves for forming the liquid chamber 2 and the plural liquid flow paths 2 are formed, as will be explained later in relation to Fig. 3, by adhering a wall member including the liquid flow path walls 8 on a surface of the element substrate 11.

[0049] On the top plate 15, there is formed a supply opening 4 for supplying the liquid chamber 2 with ink. The head main body 7 including the plural liquid flow paths 1 and the plural energy generation elements 12 is constituted by adjoining the element substrate 11 and the top plate 15 across the wall members, in such a manner that the energy generation elements 12 are respectively provided in the liquid flow paths 1. On the front end face of the head main body 7, namely on a face including an adjoining face of the element substrate 11 with the orifice plate 16 and a face including an adjoining face of the top plate 15 with the orifice plate 16, there are positioned the ports of the respective liquid flow paths. The orifice plate 16, adjoined to the adjoining face 5 of the element substrate 11 and that 6 of the top plate 15, is provided with plural discharge ports (hereinafter also called orifices) 3 respectively communicating with the liquid flow paths 1.

[0050] In such liquid discharge head, thermal energy generated by the energy generation element 12 acts on the ink in the liquid flow path 1 to generate a bubble on the energy generation element 12, and the ink is discharged from the discharge port 3 utilizing such bubble generation.

[0051] Fig. 3 is a view showing the assembling of the liquid discharge head shown in Figs. 1 and 2. As shown in Fig. 3, the element substrate 1 is provided thereon with heaters 12, a circuit for driving the heaters 12, and mounting pads 13 for introducing drives signals and electric energy from external circuits by wire bonding, TAB bonding or ACF connection. These components can be prepared by a general semiconductor process.

[0052] Then, on the above-mentioned substrate, there are prepared wall members 14 including liquid flow path walls 8. The semiconductor photolithographic technology can be applied for forming these wall members. Since these wall members generally have a width of about 5 to 15 μm and a height of about 10 to 100 μm, the applicable photolithographic technology is preferably a thick film technology, employed for example electroplating or magnetic heads. Also the material constituting the walls is required to have a high resolution and ink resistant property. An example of the material employable most advantageously is a photosensitive epoxy resist SU-8, supplied by Microchemical Corp., U.S.A. Such epoxy resin is not hydrolyzed even by the strongly alkaline ink for ink jet recording, and can provide an extremely sharp structure because of the generally low molecular weight of epoxy resin.

[0053] Such photosensitive epoxy resin can be any of those described in the U. S. Patent Nos. 4,882,245, 4,940,651, 5,026,624, 5,102,772, 5,229,251, 5,278,010 and 5,304,457. Such liquid resin material can be patterned by coating and drying on a silicon substrate for example by spin coating, roller coating, spray coating etc., then pattern exposure with a common UV exposure apparatus, followed by PEB (post exposure bake) and development with developer.

[0054] The top plate 15 having the ink supply opening 14 can be prepared in various fine working methods. Most commonly there can be employed anisotropic etching process of silicon. In this process, on a silicon wafer having silicon oxide films on both surfaces, the silicon oxide film is patterned by a common photolithographic process and silicon is etched by aqueous alkali solution to form a penetrating hole. For the alkali of such aqueous solu-

tion, there can be advantageously employed inorganic alkali such as sodium hydroxide or potassium hydroxide, or organic alkali such as TMAH (tetramethyl ammonium hydroxide). Also there may be employed a process with grinding particles such as sandblasting, or a laser process employing for example a YAG laser.

[0055] Thus prepared top plate requires surface protection if the ink resistance is insufficient. It can be achieved for example by a method of coating an alkali resistant resin by solvent coating, or a method of forming a film of an inorganic material by evaporation, sputtering or CVD.

[0056] As the liquid discharge head employing an orifice plate consisting of silicon, intends to use components of a same linear expansion coefficient even in a long-sized head, there is employed a silicon top plate utilizing the aforementioned anisotropic etching process of silicon. Also for surface protection with satisfactory covering property and ink resistance, it is most preferable to form silicon nitride by LP-CVD (low pressure chemical vapor deposition) or silicon oxide by thermal oxidation.

[0057] The heater board bearing the wall members and the top plate are adhered for example with an adhesive material. There can be employed any general-purpose adhesive material, but an epoxy adhesive is most preferred in consideration of the high ink resistance. The epoxy resin can two-liquid type in which a main material and a hardening agent are separately supplied, or one-liquid type in which both are mixed in advance.

[0058] In case of two-liquid type, after the mixing of the main liquid and the hardening agent, the mixture is coated on the surface of the top plate prepared as explained in the foregoing or on the faces of the walls formed on the heater board for example by a printing method such as screen printing, a transfer method or a roller coating method, and the adhesive is hardened after the adjoining of the top plate and the heater board. Also in case one-liquid type, the adhesive is coated by the above-described method and is hardened under the predetermined condition after the adjoining. Also the photosensitive epoxy resin employed as the wall material can be used for adjoining, by coating with the above-described method and hardening by UV light irradiation.

[0059] Thus adjoined substrates are divided into individual chips by an ordinary dicer to obtain a part to which the orifice plate is to be adhered. In case of preventing intrusion of the dusts at the dicing operation into the ink flow paths, ordinary resin may be dissolved in solvent and filled into the flow paths prior to the dicing operation. For such resin, there may be employed resin which is soluble in ordinary solvent, has a relatively low molecular weight and is hard. Examples of most preferred resin includes phenolic resin such as cresol-novolac or phenol-novolac, and styrene resin such as polystyrene or poly-α-methylstyrene.

[0060] The chip prepared as explained in the foregoing and the orifice plate consisting of silicon can be adhered by coating adhesive material on the chip in advance, then adjoining the orifice plate with alignment and then hardening the adhesive material. The adhesive material and the coating method therefor can be same as those employed in the above-described adhesion of the top plate and the heater board. In this adhesion, however, the material and the coating method have to be selected more strictly, since, in this case, the eventual intrusion of the adhesive material into the ink flow path results in defective ink discharge. In case of employing the adhesive of two-liquid type, the hardening of the adhesive proceeds from the mixing of the main agent and the hardening agent with continuous change of viscosity in time, so that the strict control of flowability is extremely difficult. Also in case of dissolving and coating the adhesive of one-liquid type in solvent, there may result intrusion of the adhesive into the ink flow path or uneven coating of the adhesive by the heat applied in drying the solvent.

[0061] Most preferably there can be employed a method of coating and drying an adhesive material, which is solid at the room temperature, on a film such as of polyethylene terephthalate (PET) and transferring such adhesive to the adjoining face by thermal transfer. In order to achieve satisfactory transfer and satisfactory coating of the adhesive without forming the film thereof on the ink discharge ports, it is necessary to determine the process conditions such as the material of the adhesive, thickness thereof, transfer conditions (temperature, pressure and rubber hardness of the platen) etc.

[0062] In the above-described adhering operation of the orifice plate, in order to prevent positional aberration between the ink discharge ports formed in the orifice plate and the ink flow paths, the orifice plate may be provided in advance with a positioning protrusion as explained in the foregoing, whereby the satisfactory alignment can be achieved with a simple apparatus. Such protrusion also prevents intrusion of the adhesive into the ink discharge port, even if the viscosity of the adhesive is lowered at the hardening thereof.

[0063] After the adjoining of the orifice plate, a water-repellent agent is preferably coated on an ink discharging surface of the silicon orifice plate, in order to improve the ink resistance and to prevent wetting by the ink. The material and the coating method therefor can be same as those explained in the foregoing.

[0064] In using the liquid discharge head of the above-described configuration in a bubble jet printer which is a liquid discharge recording apparatus, in order to obtain ink discharge capable of an image of recently required photographic quality, it is necessary to discharge ink droplets in the amount of 2 to 50 picoliters at a frequency of about 10 kHz. For discharging the ink droplets with such amount and such discharge speed, the orifice plate 16 should be formed with a thickness of 20 to 100 micrometers and the discharge port 3 should be formed with a diameter of 15 to 30 micrometers.

[0065] In the following there will be explained, with reference to Figs. 4A1, 4A2, 4B, 4C1, 4C2, 4D1, 4D2, 4E1 and 4E2, a particular method of preparing the orifice plate

shown in Figs. 1 and 2.

[0066] Figs. 4A1, 4A2, 4B, 4C1, 4C2, 4D1, 4D2, 4E1 and 4E2 show further details of a method of preparing a particular orifice plate 16 shown in Figs. 1 and 2, wherein Figs. 4A1, 4B, 4C1, 4D1 and 4E1 are cross-sectional views while Figs. 4A2, 4C2, 4D2 and 4E2 are perspective views. Each view and description relating to the preparation of the orifice plate 16 correspond to a single liquid discharge head, namely a single chip, but in practice several ten to several hundred chips are positioned on a silicon wafer of 4 to 12 inches in diameter, so that plural orifice plates 16 are produced simultaneously from a silicon wafer. Also Figs. 16A, 16B, 16C and 16D are cross-sectional views showing the flow of producing process, with emphasis on the shape of the hole to be formed in the orifice plate in the process shown in Figs. 4A1, 4A2, 4B, 4C1, 4C2, 4D1, 4D2, 4E1 and 4E2.

[0067] At first there is prepared a silicon substrate 21 of a thickness of 625 μm as shown in Figs. 4A1 and 4A2.

[0068] Then, on the surface of the silicon substrate 21, an Al layer is formed with a thickness of 8 μm by sputtering.

[0069] Then, on the Al layer on the silicon substrate 21, a resist material is coated with a thickness of 8 μm and is patterned in order to form, on the silicon substrate 21, discharge ports 3 shown in Fig. 1 and a groove-shaped plate dividing pattern for dividing the silicon substrate 21 into the individual chips. The resist was composed of Shipley SJR-5740, was coated with a coating apparatus CDS-600 supplied by Canon Inc. and was patterned by an exposure apparatus MPA-600 supplied by Canon Inc.

[0070] Then the patterned resist is used as a mask to dry etch the Al layer on the silicon substrate 21, thereby forming thereon an etching mask A1 layer 22 bearing a pattern of openings 22a in positions corresponding to the discharge ports 3. This dry etching also forms, on the Al layer 22, grooves for dividing the silicon substrate 21, corresponding to the groove-shaped plate dividing pattern. The dry etching was conducted with chlorine gas and a dry etching apparatus NLD-800 supplied by Alvac Co. The Al layer was etched in such dry etching apparatus, with a power of 1000 W, a bias of 100 W and a pressure of 0.8 Pa.

[0071] Then the resist on the Al layer 22 is removed by ashing.

[0072] Then the Al layer 22 is used as a mask to deep etch exposed portions of the silicon substrate 21 at the side of the Al layer 22 by dry etching ions 23 as shown in Fig. 4B, thereby forming recessed holes 21a in plural units with a depth of 50 + 5 to 50 μm in positions corresponding to the discharge ports 3 and a groove-shaped plate dividing pattern 21b for dividing the silicon substrate 21 into plural orifice plates, on the surface of the silicon substrate 21, as shown in Figs. 4C1 and 4C2. The depth of the plate dividing pattern 21b is 50 + 5 to 50 μm as in the case of the holes 21a. Thus there is formed, on the surface of the silicon substrate 21, a pattern including the plate dividing pattern 21b and the plural holes 21a. This step was executed with a dry etching apparatus NLD-800 of Alvac Co. and SF_6 as the etching gas. In the dry etching apparatus, the silicon substrate 21 was etched with a power of 1000 W, a bias of 250 W and a pressure of 1.0 Pa to attain deep etching with a substantially straight cross-sectional shape of a depth of 50 + 5 to 50 μm. After the etching with SF_6, as shown in Fig. 16A, the hole 21a is provided, at the open end thereof, with a tapered portion 29a having a gradually decreasing cross section from the liquid flow path side to the discharge port side, but is composed of a straight portion 27b, having a substantially constant cross section, in most of the hole 21a-including the bottom portion thereof. As the tapered portion 29a has a roughed surface, etching with CF_4 is further executed in order to smooth the surface of such tapered portion 29a, with a power of 1000 W, a bias of 50 W and a pressure of 1.0 Pa. After the etching with CF_4, the surface of the tapered portion 29c shown in Figs. 16A to 16D, at the open end of the hole 21a, is made smooth.

[0073] With thus formed hole 21a, the silicon substrate 21 is thinned from the reverse side to the position of the straight portion 27d as will be explained later, whereby obtained is an opened port 21a with a substantially constant diameter regardless of the fluctuation in the removed thickness of the silicon substrate 21. As the bottom of the hole 21a is often not formed squarely, the silicon removing operation is not terminated in a state where the hole 21a is merely exposed by is preferably continued until the straight portion 27b is securely reached. Such formation of the discharge ports in the silicon substrate 21 allows to obtain those having a uniform port diameter and a tapered shape showing gradually decreasing cross section toward the ink discharging side.

[0074] Fig. 16A shows the cross section after etching with SF_6, while Fig. 16B shows the cross section after etching with CF_4. After the etching with SF_6, as shown in Fig. 16A, the hole 21a is a tapered portion 29a at the open end, but is composed, in most of the hole 21a including the bottom thereof, of a straight portion 27 having a substantially constant shape along the direction of depth of the hole 21a. After the etching with CF_4, as shown in Fig. 16B, the open end of the hole 21a constitutes a tapered portion 29c wider than the tapered portion 29a shown in Fig. 16A while the remaining portion of the hole 21a constitutes a straight portion 27d with a constant cross section along the direction of depth. Consequently the straight portion 27d becomes narrower than the straight portion 27b shown in Fig. 16A.

[0075] The tapered shape of the discharge port 3, as shown in Figs. 1 and 2, can be adjusted as desired, by varying the bias value.

[0076] Then the Al layer 22 on the silicon substrate 21 is removed by a mixture of nitric acid, phosphoric acid and acetic acid, as shown in Figs. 4C1 and 4C2. Then, in order to protect a surface, coming into contact with ink,

of the silicon substrate 21, an SiN protective film is formed with a thickness of 2 μm by CVD, as shown in Fig. 16C, on the surface of the silicon substrate 21 at the side of the holes 21a and on the entire internal walls of the holes 21a.

[0077] Then, as shown in Figs. 4D1 and 4D2, the surface of the silicon substrate 21 at the side of the holes 21a is adhered to a UV peelable tape, and the reverse surface of the silicon substrate 21 is ground and polished to thin the silicon substrate 21 to a thickness of 50 μm. In this operation, the silicon substrate 21 is adhered to the UV peelable tape 24, which is a back-fringing tape for maintaining, to a certain extent, the strength of the silicon substrate 21 in the grinding/polishing operation thereof. After the polishing of the reverse side of the silicon substrate 21, the UV peelable tape is peeled off by UV irradiation, whereby the bottom of each hole 21a is opened on the reverse surface of the silicon substrate 21 to constitute a penetrating hole, thereby forming a discharge port 3 in the silicon substrate 21, and the silicon substrate 21 is divided into plural orifice plates 16 according to the plate dividing pattern 21b. The thinning of the silicon substrate 21 may also be achieved by etching of the reverse surface of the silicon substrate 21.

[0078] Through the above-explained steps, there is obtained the orifice plate 16, provided by forming the discharge ports 3 in the silicon substrate 21, as shown in Figs. 4C1 and 4C2.

[0079] In this state, as shown in Fig. 16D, the opening of the discharge port 3 at the side of smaller cross section is formed in a part of the straight portion 27d close to the tapered portion 29c so that the front end portion of the discharge port 3 at the side of opening contains a certain straight portion of the constant cross section, whereby the discharge ports 3 can have a uniform port diameter. In case the entire discharge port 3 is to be tapered, the opening of the discharge port 3 at the side of smaller cross section may be positioned at the boundary between the tapered portion 29c and the straight portion 27d or provided in a position of the tapered portion 29c close to the straight portion 27d.

[0080] A liquid discharge head was prepared utilizing thus obtained orifice plate and executing assembly in the same manner as explained in the foregoing with reference to Fig. 3. The element substrate 11 and the top plate 15 were adhered to the orifice plate 16 with epoxy adhesive with a thickness of 2 μm.

[0081] The liquid discharge head prepared with the orifice plate 16 was subjected to a heat cycle test between -30°C and +60°C, together with a comparative sample prepared with an orifice plate of polysulfone resin. While the comparative sample prepared with the polysulfone orifice plate showed peeling of the orifice plate for the orifice plate of a length of 50 mm or larger along the nozzle array, the head assembled with the silicon orifice plate, did not show peeling of the orifice plate 16.

[0082] As explained in the foregoing, the orifice plate 16 having plural discharge ports 3 in the silicon substrate 21 is prepared by forming the recessed holes 21a thereon by etching and thinning the silicon substrate 21 from the reverse side thereof. It is thus rendered possible to produce a large-sized liquid discharge head of high reliability and to produce a large-sized liquid discharge head of high reliability also in case of constructing the liquid discharge head with the orifice plate consisting of silicon as explained in the foregoing.

[0083] In the following there will be explained, with reference to Figs. 16A, 16B, 16C and 16D, a variation of the particular method for producing the orifice plate explained in the foregoing with reference to Figs. 4A1, 4A2, 4B, 4C1, 4C2, 4D1, 4D2, 4E1 and 4E2. Figs. 16A, 16B, 16C and 16D are cross-sectional views showing a variation of the method for producing the orifice plate explained in the foregoing with reference to Figs. 4A1, 4A2, 4B, 4C1, 4C2, 4D1, 4D2, 4E1 and 4E2. In comparison with the above-explained producing method, the producing method for the orifice plate to be explained with reference to Figs. 17A, 17B and 17C is different principally in that, in the formation of the hole for the discharge port in the silicon substrate 21 by dry etching, an SiO_2 layer of a thickness of 2 μm is as the mask instead of the Al layer of thickness of 8 μm.

[0084] The silicon substrate 21 is dry etched, utilizing an SiO_2 layer 28 of a thickness of 2 μm formed on the surface of the silicon substrate 21 and having a predetermined pattern corresponding to the discharge port and the plate dividing pattern as a mask, whereby holes 21a are formed on the silicon substrate 21 for forming the discharge ports. In such dry etching step, the plural holes 21a are formed in the silicon substrate 21 by a cycled etching in which repeated are dry etching for 10 seconds with SF_6 as the etching gas and dry etching for 30 seconds with CF_2 as the etching gas.

[0085] The dry etching of the silicon substrate 21 with the SiO_2 layer 28 as the mask allows to form the holes 21a of a constant cross section along the direction of depth, on the silicon substrate 21.

[0086] Then, as shown in Fig. 17B, an SiN protective film 29 is formed by CVD on the entire surface of the SiO_2 layer 28 and the entire internal wall of the holes 21a.

[0087] Then, as shown in Fig. 17C, the silicon substrate 21 is thinned from the reverse side thereof to cause the holes 21a to penetrate through the substrate 21, thereby forming the discharge ports 3 therein. The opening of the discharge port 3 is formed in an area, having a constant cross section, of the hole 21a. In this manner there is prepared the orifice plate 16 constructed by forming the discharge ports 3 in the silicon substrate 21.

[0088] The producing method for the orifice plate, explained with reference to Figs. 17A, 17B and 17C, allows to form the holes 21a with a constant cross section along the direction of depth, and to form the opening of the discharge port 3 in a region where the cross section is constant. The liquid discharge head produced with the orifice plate prepared by the producing method shown in Figs. 17A, 17B and 17C is excellent in reliability and al-

lows an increase in the head dimention, like the liquid discharge head produced with the orifice plate prepared according to the producing method shown in Figs. 4A1, 4A2, 4B, 4C1, 4C2, 4D1, 4D2, 4E1 and 4E2 and Figs. 16A, 16B, 16C and 16D.

[0089] Fig. 5 is a perspective view showing another liquid discharge head comprising a silicon plate and Fig. 6 is a cross-sectional view of the liquid discharge head shown in Fig. 5, along the liquid flow path. In comparison with the liquid discharge head shown in Fig. 1, the liquid discharge head shown in Figs. 5 and 6 is different only in the orifice plate and in that a projection part for fitting with the liquid flow path of the head main body is formed around the discharge port, on a surface of the orifice plate facing the head main body. In Figs. 5 and 6, components same as those in Fig. 1 are represented by numbers same as in Fig. 1.

[0090] In the present liquid discharge head the orifice plate 16 shown in Fig.1 is replaced by an orifice plate 46 shown in Figs. 5 and 6. The orifice plate 46 is composed of silicon, as in the case of the orifice plate 16 in Fig. 1. As in the case of the orifice plate 16, the orifice plate 46 is adjoined to the front end face of the head main body 7, namely to the adjoining face 5 of the element substrate 11 and the adjoining face 6 of the top plate 15, and is provided with plural discharge ports 46a respectively communicating with the flow paths 1. The orifice plate 46 is provided, around the discharge ports 46a on the adjoining face of the orifice plate 46 with the head main body 7, with independent projections 47 respectively corresponding to the discharge ports 46a as shown in Figs. 5 and 6. The orifice plate 46 is adjoined to the adjoining faces 5, 6 in a state in which each projection enters and is fitted with the liquid flow path 1.

[0091] Fig. 7 is a view showing the assembling of the liquid discharge head shown in Figs. 5 and 6. As shown in Fig. 7, wall members 14 including liquid flow path walls 8 are formed on the surface of an element substrate 11, and a top plate 15 including a supply opening 14 is adjoined to a face of the wall members 14 opposite to the element substrate 11. An orifice plate 46 is adhered to the front end face of the element substrate 11, wall members 14 and top plate 15. Recesses 47 of the orifice plate 46 are fitted into liquid flow paths 1 of the head main body 7, so that the alignment is accurate even if the epoxy adhesive is transferred to the top plate 15 and the element substrate 11, whereby a liquid discharge head excellent in mass producibility and reliability can be obtained.

[0092] In the following there will be explained, with reference to Figs. 8Al, 8A2, 8B, 8C1, 8C2, 8D1, 8D2, 8E1 and 8E2, a method of preparing the orifice plate shown in Figs. 5 and 6.

[0093] Figs. 8A1, 8A2, 8B, 8C1, 8C2, 8D1, 8D2, 8E1 and 8E2 show a method of preparing the orifice plate 46 shown in Figs. 5 and 6, wherein Figs. 8A1, 8B, 8C1, 8D1 and 8E1 are cross-sectional views while Figs. 8A2, 8C2, 8D2 and 8E2 are perspective views. Each view and description relating to the preparation of the orifice plate 46 corresponding to a single liquid discharge head, namely a single chip, but in practice several ten to several hundred chips are positioned on a silicon wafer of 4 to 12 inches in diameter, so that plural orifice plates 46 are produced simultaneously from a silicon wafer.

[0094] On the silicon substrate, a resist material is coated with a thickness of 2 μm and is patterned in order to form projections 47 of a height of about 4 μm in positions corresponding to the discharge ports 46a and areas therearound. The resist was composed of Shipley SJR-5740, was coated with a coating apparatus CDS-600 supplied by Canon Inc. and was exposed by an exposure apparatus MPA-600 supplied by Canon Inc.

[0095] Then the patterned resist is used as a mask to dry etch the silicon substrate, thereby forming a silicon substrate 31 provided thereon with plural projections 31b as shown in Figs. 8A1 and 8A2. Each projection 31b has a height of about 4 μm and is formed in a position corresponding to the discharge port 46a shown in Figs. 5 and 6 and in an area therearound. The dry etching was conducted with SF_6 and a dry etching apparatus NLD-800 supplied by Alvac Co. The silicon substrate 31 was dry etched for 3 minutes in the dry etching apparatus with a power of 1000 W, a bias of 50 W and a pressure of 0.8 Pa.

[0096] Then, on a surface of the silicon substrate 31 at the side of the projections 31b, an Al layer is formed with a thickness of 8 μm by sputtering so as to cover the projections 31b.

[0097] Then, on the Al layer on the silicon substrate 21, a resist material is coated with a thickness of 8 μm and is patterned in order to from the discharge ports 46 shown in Fig. 5 and a groove-shaped plate dividing pattern for dividing the silicon substrate 31 into the individual chips. The resist was composed of Shipley SJR-5740, was coated with a coating apparatus CDS-600 supplied by Canon Inc. and was patterned by an exposure apparatus MPA-600 supplied by Canon Inc.

[0098] Then the patterned resist is used as a mask to dry etch the Al layer on the silicon substrate 31, thereby forming thereon an etching mask Al layer 32 bearing a pattern of openings 32a in positions corresponding to the discharge ports 46, as shown in Figs. 8A1 and 8A2. This dry etching also forms, on the A1 layer 32, grooves for dividing the silicon substrate 21, corresponding to the groove-shaped plate dividing pattern. The dry etching was conducted with chlorine gas and a dry etching apparatus NLD-800 supplied by Alvac Co. The Al layer was etched in such dry etching apparatus, with a power of 1000 W, a bias of 50 W and a pressure of 0.8 Pa.

[0099] Then the resist on the Al layer 32 is removed by ashing.

[0100] Then, as shown in Fig. 8B, the Al layer 32 is used as a mask to deep etch exposed portions of the silicon substrate 31 and the side of the Al layer 32 by dry etching ions 33, thereby forming recessed holes 31a in plural units with a depth of 70 + 5 to 50 μm in positions

corresponding to the discharge ports 46 and a groove-shaped plate dividing pattern 31b for dividing the silicon substrate 31 into plural orifice plates, on the surface of the silicon substrate 31, as shown in Figs. 8C1 and 8C2. The depth of the plate dividing pattern 31b is 70 + 5 to 50 μm as in the case of the holes 31a. Thus there is formed, on the surface of the silicon substrate 31, a pattern including the plate dividing pattern 31b and the plural holes 31a, and the remaining portions of the projections 31b constitute the projections 47 shown in Figs. 5 and 6, whereby the plural projections 47 are formed on the silicon substrate 31. This step was executed with a dry etching apparatus NLD-800 of Alvac Co. and SF_6 as the etching gas. In the dry etching apparatus, the silicon substrate 31 was etched with a power of 1000 W, a bias of 200 W and a pressure of 1.0 Pa to attain etching of the silicon substrate 31.

[0101] Then the Al layer 32 on the silicon substrate 31 is removed by a mixture of nitric acid, phosphoric acid and acetic acid, as shown in Figs. 8C1 and 8C2. Then, in order to protect a surface, coming into contact with ink, of the silicon substrate 31, an SiN layer (not shown) is formed with a thickness of 2 μm by CVD on the entire surface of the silicon substrate 31 at the side of the holes 31a and on the entire internal walls of the holes 31a.

[0102] Then, as shown in Figs. 8D1 and 8D2, the surface of the silicon substrate 31 at the side of the holes 31a is adhered to a UV peelable tape 34, and the reverse surface of the silicon substrate 31 is ground and polished to thin the silicon substrate 31 until the thickness thereof including the projections 47 becomes 70 μm. In this operation, the silicon substrate 31 is adhered to the UV peelable tape 24 for maintaining, to a certain extent, the strength of the silicon substrate 31 in the grinding/polishing operation thereof. Such elimination of the reverse surface of the silicon substrate 31 causes, as shown in Figs. 8E1 and 8E2, the bottom of each hole 21a to open on the reverse surface of the silicon substrate 31 to constitute a penetrating hole, thereby forming a discharge port 46a in the silicon substrate 31, and the silicon substrate 21 to be divided into plural orifice plates 46 according to the plate dividing pattern 31c. Through the above-explained steps, there is obtained the orifice plate 16, provided by forming the plural projections 47 and the plural discharge ports 46a in the silicon substrate 31.

[0103] A liquid discharge head is prepared by adhering thus obtained orifice plate to the head main body, including the energy generation elements and the liquid flow paths. The adhesive is most preferably composed of epoxy resin which is provided with high ink resistance and a high adhesion strength. The epoxy adhesive can be a general two-liquid type or a one-liquid type that can be hardened at a high temperature. In hardening such adhesive, the orifice plate has to be pressed to the discharge element under a load, and may be displaced under the load application. Also the adhesive may overflow to clog the ink discharge port. In order to prevent such drawbacks, a projection is preferably formed around the discharge port on the adjoining face of the orifice plate. The positional aberration between the ink flow path and the discharge port at the adjoining operation can be prevented by fitting the projection into the ink flow path. Also the projection can prevent intrusion of the adhesive into the ink flow path, since the eventually overflowing adhesive forms a meniscus at such projection and is prevented from further flowing.

[0104] Figs. 9A, 9B, 9C, 9D, 9E, 9F and 9G show a particular method for producing a liquid discharge head, and Fig. 10 is a flow chart of the producing process of the liquid discharge head to be explained with reference to Figs. 9A, 9B, 9C, 9D, 9E, 9F and 9G.

[0105] This producing method is an extension of the aforementioned producing method. As a general application, the ink jet recording is used in four-color recording with black, cyan, magenta and yellow or in six-color recording further including pale cyan and pale magenta. For mutual alignment of the placement of the ink dots of different colors, it is necessary to mutually align the nozzles of different colors, and it is desirable to align the nozzles of different colors within an orifice plate. In the present producing method the silicon substrate is reinforced, at the thinning operation thereof, with a frame member consisting of silicon or glass having a linear expansion coefficient similar to that of silicon, instead of the UV peelable tape, thereby achieving mutual alignment of the nozzle arrays while realizing cost reduction.

[0106] At first there are prepared a plate-shaped frame member 53 having a hole 54 as shown in Fig. 9A, and a silicon substrate 51 having projections 52 as shown in Fig. 9B. The frame member 53 can be composed of silicon or glass having a linear expansion coefficient similar to that of silicon. The present member 53 will be explained by a case employing glass of a linear expansion coefficient similar to that of silicon.

[0107] For preparing the frame member 53, a glass wafer of a thickness of 625 μm is prepared and the hole 54 is patterned therein. The frame member 53 was composed of glass SG-2 supplied by Hoya Glass Co. and the hole 54 was formed by blasting.

[0108] For preparing the silicon substrate 51 having plural projections 52, there is at first prepared a silicon substrate of a thickness of 625 μm, and a resist material is coated thereon with a thickness of 2 μm. Then the resist is patterned in order to form projections 52 of a height of about 4 μm in positions corresponding to the discharge ports and areas therearound. The resist was composed of Shipley SJR-5740, was coated with a coating apparatus CDS-600 supplied by Canon Inc. and exposed by an exposure apparatus MPA-600 supplied by Canon Inc.

[0109] Then the patterned resist is used as a mask to dry etch the silicon substrate, thereby forming a silicon substrate 51 provided thereon with plural projections 52 as shown in Fig. 9B. Each projection 52 has a height of about 4 μm and is formed in a position corresponding to the discharge port and in an area therearound. In the

state shown in Fig. 9B, the silicon substrate 51 has a thickness a, including the projections 52, of 625 μm which is same as the original thickness of the silicon substrate. The dry etching was conducted with SF_6 as the etching gas and a dry etching apparatus NLD-800 supplied by Alvac Co. The silicon substrate 51 was dry etched for 3 minutes in the dry etching apparatus with a power of 1000 W, a bias of 50 W and a pressure of 0.8 Pa.

[0110] Then, after the removal by ashing of the resist used for forming the projections 52 on the silicon substrate 51, a thermal oxidation film (SiO_2, not shown) is formed with a thickness of 1 μm on a surface of the silicon substrate 51 at the side of the projections 52. Thus the thermal oxidation film is formed also on the entire end and lateral faces of the projections 52. Then, a resist material is coated on the entire surface of the thermal oxidation film on the silicon substrate 51 and is patterned in order to form openings in positions corresponding to the discharge ports. Then the patterned resist is used as a mask to dry etch the thermal oxidation film on the silicon substrate 51. Such patterning forms, in the thermal oxidation film on the silicon substrate 51, openings in positions corresponding to the discharge ports. Then thermal oxidation film is used as a mask in forming recesses for forming the discharge ports on the silicon substrate 51 by dry etching as will be explained later.

[0111] Then the resist used for patterning the thermal oxidation film on the silicon substrate 51 is removed by ashing.

[0112] Then, as shown in Fig. 9C, the frame member 53 is anodic adjoined to a surface of the silicon substrate 51 at the side of the projections 52, in such a manner that the projections 52 of the silicon substrate 51 are positioned within the hole 54 of the frame member 53. The adjoining of the silicon substrate 51 and the frame member 53 was executed by an apparatus SB-6 supplied by Carl Zuess Co. The anodic adjoining of the silicon substrate 51 and the frame member 53 was conducted in such adjoining apparatus for 1 hour at 350°C. The method here employed anodic adjoining of the silicon substrate 51 and the frame member 53, but they may be adjoined instead by vacuum thermal adjoining or with an adhesive material.

[0113] Then, as shown in Fig. 9D, the above-mentioned thermal oxidation film (not shown) on the silicon substrate 51 is used as a mask for deep dry etching the exposed portions in the end faces of the projections 52 on the silicon substrate 51 by dry etching ions 56, thereby forming plural recessed holes 58 of a depth of 50 +..5 to 50 μm in positions corresponding to the discharge ports. As shown in Fig. 9D, a remaining portion of the projection 52 constitutes a projection 57 for fitting in the liquid flow path 1 of the head main body 7.

[0114] Then, as shown in Fig. 9E, the reverse surface of the silicon substrate 51 is ground and polished to thin the silicon substrate 51 until the thickness b thereof, including the projections 57, is reduced to 50 μm. Such thinning of the silicon substrate 51 causes, as shown in Fig. 9C, the bottom of each hole 58 to open in the reverse surface of the silicon substrate 51, thereby forming a penetrating hole, whereby discharge ports 58a are formed in the silicon substrate 51.

[0115] Then an SiN protective film is formed with a thickness of 2 μm by CVD on the entire internal walls of the discharge ports 58a. The protective film was composed of silicon nitride, but it may be replaced by a thermal oxidation film, silicon oxide or silicon carbide formed by CVD, or gold, platinum, Pd, Cr, Ta or W formed by electroplating or sputtering.

[0116] Then, as shown in Fig. 9F, a water-repellent fluorine film 59 is transfer laminated on a surface of the silicon substrate 51 opposite to the side of the projections 57, so as not to block the discharge ports 58a.

[0117] Then, as shown in Fig. 9G, there is cut off, by dicing, an orifice plate containing four nozzles arrays, corresponding to four liquid discharge heads or four element chips. In this manner there is obtained an orifice plate 51a, constructed by forming the projections 57 and the discharge ports 58a of four arrays on the silicon substrate 51.

[0118] Then, in order to adjoin a separately prepared head main body 7, obtained by adjoining an element substrate 11 and a top plate 15, to the adjoined member of the silicon substrate 51 and the frame member 53, epoxy resin is transferred onto a front end face of the head main body 7 where the open ends of the liquid flow paths 1 are located. Then the front end of the head main body 7 is directed to and inserted into the hole 54 of the adjoined member of the silicon substrate 51 and the frame member 53, whereby the head main body 7 is positioned with respect to the orifice plate 51a. The mutual alignment of the orifice plate 51a and the head main body 7 is achieved by fitting the projections 57 of the orifice plate 51a in the liquid flow paths 1 of the head main body 7.

[0119] In this manner the head main body 7 is adhered to the orifice plate 51a, with such mutual alignment therebetween.

[0120] Then the gap between the head main body 7 and the frame member 53 is filled with heat conductive resin containing fine metal particles and having high thermal conductivity. Thus the liquid discharge head having four nozzle arrays can be improved in the strength, while securing thermal conduction between the head main body 7 and the frame member 53.

[0121] Fig. 11 is a perspective view of a liquid discharge head, constructed by adhering four head main bodies to the adjoined member of the orifice plate and the frame member. As shown in Fig. 11, the liquid discharge head can be prepared by inserting the head main body 7 in each of the four holes 54 of the frame member 53 and adjoining each head main body 7 to the orifice plate 51a in the above-described method.

[0122] Through the above-described steps, there is produced a liquid discharge head having four nozzles arrays which are integrated by alignment with an orifice plate.

[0123] Figs. 12A1, 12A2, 12B, 12C1, 12C2, 12D, 12E1, 12E2, 12F, 12G1 and 12G2 are views showing steps of preparing an orifice plate of the liquid discharge head, in a particular method for producing a liquid discharge head, wherein Figs. 12A1, 12B, 12C1, 12D, 12E1, 12F and 12G1 are cross-sectional views while Figs. 12A2, 12C2, 12E2 and 12G2 are perspective views.

[0124] In comparison with the above producing method, the present producing method is different in that the protective film formed on the internal face of the discharge port at the preparation of the orifice plate is caused to protrude from a surface of the orifice plate opposite of the head main body thereby forming a projection.

[0125] At first there is prepared a silicon substrate 71 of a thickness of 625 μm as shown in Figs. 12A1 and 12A2, and an A1 layer is formed thereon with a thickness of 8 μm by sputtering.

[0126] Then, on the Al layer on the silicon substrate 71, a resist material is coated with a thickness of 8 μm and is patterned in order to form, on the silicon substrate 71, discharge ports and a groove-shaped plate dividing pattern for dividing the silicon substrate 71 into the individual chips.

[0127] Then the patterned resist is used as a mask to dry etch the Al layer on the silicon substrate 71, thereby forming thereon an etching mask Al layer 72 bearing a pattern of openings 72a in positions corresponding to the discharge ports, as shown in Figs. 12A1 and 12A2. This dry etching also forms, on the Al layer 72, grooves for dividing the silicon substrate 71, corresponding to the groove-shaped plate dividing pattern.

[0128] Then the resist on the Al layer 72 is removed by ashing.

[0129] Then the Al layer 72 is used as a mask to deep etch exposed portions of the silicon substrate 71 at the side of the Al layer 72 by dry etching ions 73 as shown in Fig. 4B1, thereby forming recessed holes 71a in plural units with a depth of 70 + 5 to 50 μm in positions corresponding to the discharge ports and a groove-shaped plate dividing pattern 72b for dividing the silicon substrate 71 into plural orifice plates, on the surface of the silicon substrate 71, as shown in Figs. 12C1 and 12C2. The depth of the plate dividing pattern 72b is 70 + 5 to 50 μm as in the case of the holes 71a. Thus there is formed, on the surface of the silicon substrate 71, a pattern including the plate dividing pattern 72b and the plural holes 71a.

[0130] Then the Al layer 72 on the silicon substrate 71 is removed by a mixture of nitric acid, phosphoric acid and acetic acid, as shown in Figs. 12C1 and 12C2.

[0131] Then, in order to protect a surface, coming into contact with ink, of the silicon substrate 71, an SiN protective film 75 is formed with a thickness of 2 μm by CVD, as shown in Fig. 12D, on the surface of the silicon substrate 71 at the side of the holes 71a and on the entire internal walls of the holes 71a. The present protective film was composed of silicon nitride, but it may be replaced by a thermal oxidation film, silicon oxide or silicon carbide formed by CVD, or gold, platinum, Pd, Cr, Ta or W formed by electroplating or sputtering. This thickness of the protective film is preferably within a range of 0.5 to 2 μm, since an excessively thick protective film increases the stress, leading to breakage of the silicon substrate at the grinding/polishing operation thereof, and also since an excessive hydrophilic portion on the projection tends to cause deflected flight of the liquid droplet.

[0132] Then, as shown in Figs. 12E1 and 12E2, the surface of the silicon substrate 71 at the side of the holes 71a is adhered to a UV peelable tape 74, and the reverse surface of the silicon substrate 71 is ground and polished to thin the silicon substrate 71 to a thickness of 70 μm. In this operation, the silicon substrate 71 is adhered to UV peelable tape 74, in order to maintain, to a certain extent, the strength of the silicon substrate 71 in the grinding/polishing operation thereof. Such grinding of the reverse surface of the silicon substrate 71 causes, as shown in Fig. 12F, each hole 71a to open on the reverse surface of the silicon substrate 71 to constitute a penetrating hole, whereby discharge ports 71b are formed in the silicon substrate 71, and the silicon substrate 71 is divided into plural orifice plates 76 according to the plate dividing pattern 72b.

[0133] Then, as shown in Figs. 12G1 and 12G2, the surface layer of the silicon substrate 71, on the side not covered by the protective film 75, is removed by alkaline etching with KOH, whereby the protective film 75 is made to protrude from such surface of the silicon substrate 71 to constitute a projection 75a. In this manner there is obtained the orifice plate 76 to be adjoined to the head main body of the liquid discharge head, and having a discharging portion constructed by the protective film 75 constituting the internal wall of the discharge port 71b and protruding from the surface of the orifice plate 75.

[0134] Fig. 13 is a perspective view showing the assembling of the liquid discharge head, employing the orifice plate 76 prepared according to the steps shown in Figs. 12A1, 12A2, 12B, 12C1, 12C2, 12D, 12E1, 12E2, 12F, 12G1 and 12G2. After the orifice plate 76 is prepared by the above-described steps, it is adjoined to the head main body 7 consisting of the element substrate 11, wall members 14 and top plate 15 as shown in Fig. 13 to obtain the liquid discharge head. In this operation, the orifice plate 76 is adjoined in such a manner that a discharge portion 75a is positioned opposite to the head main body 7.

[0135] In the liquid discharge head employing such orifice plate 76, the presence of the SiN protective film 75, being repellent to ink, dispenses with the cleaning operation around the nozzles by blade wiping of the head surface including the discharge ports, thereby simplifying the structure of the main body of the liquid discharge recording apparatus and the control sequence thereof.

[0136] Figs. 14A1, 14A2, 14B1 and 14B2 are views showing a variation of the method for producing the orifice plate explained in the foregoing with reference to Figs. 12A1, 12A2, 12B, 12C1, 12C2, 12D, 12E1, 12E2, 12F,

12G1 and 12G2. The producing method for the orifice plate, to be explained with reference to Figs. 14A1, 14A2, 14B1 and 14B2 is same as the above-described producing method up to the step shown in Figs. 12G1 and 12G2, after which a water-repellent film is formed on the silicon substrate 71 constituting the orifice plate 76.

[0137] After the step shown in Figs. 12G1 and 12G2, a water-repellent material 79 is dispense coated by a dispenser 78, as shown in Figs. 14A1 and 14A2, on the exposed surface of the silicon substrate 71 constituting the orifice plate 76, namely the entire surface of the silicon substrate 71 constituting the discharge portion 75a by the protrusion of the protective film 75. Thus, there is formed, as shown in Figs. 14B1 and 14B2, a water-repellent film 79a on the entire surface of the silicon substrate 71 including the areas around the projections 75a.

[0138] The liquid discharge head constituted with the orifice plate 76 bearing the water-repellent film 79a avoids ink deposition around the discharge ports on the discharge face of the orifice plate 76, so that the deflected ink discharge resulting from such ink deposition is difficult to occur.

[0139] Such producing method of the orifice plate allows to form the water-repellent film also around the discharge ports, thereby providing a liquid discharge head in which the deflected ink discharge resulting from the ink deposition around the nozzles is difficult to occur.

[0140] In the present producing method for the liquid discharge head, the surface of the orifice plate 76 at the side of the head main body is not provided with the projections for entering and fitting with the liquid flow paths of the head main body, but the producing method of Fig. 5 and 6 may be applied to produce a liquid discharge head having projections for fitting with the liquid flow paths of the head main body and also having a protruding structure of the protective film constituting the internal walls of the discharge ports.

[0141] Figs. 18 and 19A to 19I are views showing another producing method for the liquid discharge head, wherein Fig. 18 is a flow chart of the producing method of an orifice plate.

[0142] The present method is different from the foregoing methods in that, after the formation of the recess or after the formation of the protective film on the silicon lateral wall of the recess, such recess is filled. In the foregoing methods, the ink discharge may become unstable, by the intrusion of the grinding material in the penetrating hole or by chipping in the grinding operation. Such phenomena can be easily prevented with particular control in the thinning step of the silicon substrate, by filling the recesses.

[0143] In the following, there will be explained, with reference to Figs. 18 and 19A to 19I, the present producing method for the liquid discharge head.

[0144] At first, on a silicon substrate 201, there are formed projections (101 in Fig. 18, Fig. 19A) for forming projections 201b for avoiding positional aberration.

[0145] The projection 201b can be formed by forming a projection 202 by dry etching on silicon, prior to the formation of a recess 201a. Such projection can be easily formed by etching with fluorine-containing gas, utilizing ordinary positive-working photoresist as a mask. The projection 202 advantageously has a height of 1 to 10 μm. For fitting with the ink flow path, there is generally preferred a fitting gap of 0.5 to 3 μm, though it is dependent on the adjoining precision of the orifice plate adjoining apparatus.

[0146] Then dry etching is executed to form a recess 201a to constitute the ink discharge port. In this operation, there is collectively formed a plate dividing pattern corresponding to the external shape of the plate (102 in Fig. 18, Fig. 19B).

[0147] The formation of the recesses 201a and the plate dividing pattern can be achieved by forming a mask member by patterning, and by dry etching with fluorine-containing gas as etchant, utilizing thus patterned mask. The mask pattern can be composed of an ordinary resist, a metal such as Al, Ta or W, silicon oxide or silicon carbide. The etching depth is required to be larger than the thickness of the finally formed orifice plate, in order that a penetrating hole constituting the discharge port is formed by the silicon thinning operation. Naturally, an unnecessarily deep etching results in deterioration of the shape of the recess, an increase in the tact time but an etching depth very close to the thickness of the orifice plate may result in an unpenetrating hole because of the loading effect.

[0148] The etching depth is preferably a value of 5 to 50 μm in addition to the depth of the discharge port. Thus, if the final thickness of the orifice plate is designed as 50 μm, the depth of the recess is preferably in a range of 55 to 100 μm.

[0149] The etching may be executed by ordinary reactive ion etching (RIE), or by electron cyclotron (ECR) etching, magnetron etching or induction coupled etching for high-speed etching.

[0150] Most preferred is an ICP-RIE recess forming process called Bosch process, in which the ICP etching and protective film deposition on the lateral wall of the etched portion are repeated at high speed.

[0151] In such etching process, etching is executed with an etchant enabling high-speed etching such as SF_6, CF_4 or NF_3, then a fluorine-containing polymer is formed on the lateral wall by deposition gas such as CHF_3, C_2F_4, C_2F_6, $C_2H_2F_2$ or C_4H_8, and these operations are repeated whereby the recesses and the plate dividing pattern are formed with a high aspect ratio at a high speed. The etching apparatus utilizing such etching process is commercialized by Alcatel Co. and STS Co.

[0152] Then, a lateral wall protective film 206 is formed on the interior of the discharge port, in order to improve the ink resistance (103 in Fig. 18, Fig. 19C).

[0153] The ink for ink jet recording is often alkaline, and may etch silicon. The silicon surface has to be protected in case such ink is to be used. The silicon surface has to be protected on the lateral wall of the trench formed

by RIE and on the surface having the discharge port. The lateral wall of the trench can be protected, after-the RIE step, by forming an ink-resistant protective film by an ordinary film forming method. Such protective film can be formed for example by thermal oxidation, CVD, sputtering or plating, and can be composed of a silicon compound such as silicon oxide or silicon nitride, or a metal such as gold, platinum, Pd, Cr, Ta or W. Most preferred is a method of forming silicon oxide by thermal oxidation or a method of forming silicon nitride by LP-CVD, in consideration of a low cost and a high covering power. Such protective film preferably has a thickness in a range of 0.1 to 5 μm.

[0154] Then a filling material is filled in the recess (104 in Fig. 18, Fig. 19D).

[0155] The penetrating hole, being formed in the back grinding, etching or grinding operation, may be subjected to intrusion of the grinding material or chipping in the grinding operation, thus resulting in unstable liquid discharging operation. For preventing such phenomena, there can be adopted a method of filling the recess 201a with a filling material 210, after the formation of the recess or after the formation of the silicon wall protecting film on the recess. A simplest method consists of introducing resin by dissolving in solvent, and thinning the silicon after the solvent is removed. The filling resin preferably has a softening temperature exceeding the temperature generated at the grinding or polishing operation, a hardness capable of preventing chipping and is easily removable by dissolving after such steps. In general, there can be advantageously employed phenolic resin such as phenol-novolak resin, cresol-novolak resin or polyvinylphenol, styrene resin such as polystyrene or poly-α-methylstyrene, or acrylic resin such as polymethyl methacrylate. Such resin can be easily filled into the recesses 201a by dissolving in solvent, coating on the silicon wafer for example by spin coating and drying for example in an oven. If bubbles remain in the recesses 201a in such operation, the coating operation may be executed in vacuum.

[0156] Instead of such resin, a metal may also be used for filling. Such metal can be filled in for example by sputtering, evaporation or CVD, and can be removed by dissolving for example in an acid after the thinning operation of silicon. The metal to be filled is advantageously a hard metal such as Ta, W, Cr or Ni.

[0157] Then a UV peelable tape constituting a back grinding tape is adhered (105 in Fig. 18, Fig. 19E). The back grinding tape is used as a supporting member for maintaining the strength of the silicon substrate at the grinding/polishing operation thereof.

[0158] Then the reverse surface of the silicon substrate 201 is ground to effect thinning thereof (106 in Fig. 18, Fig. 19F), and then is polished to remove the chipped portions of the protective film and to further thin the silicon substrate (107 in Fig. 18, Fig. 19F) whereby obtained is the orifice plate 216 having the penetrating holes for constituting the ink discharge ports.

[0159] The thinning of the silicon substrate 201 is generally executed by a method, after adhering the UV peelable tape 204 on the surface, of grinding the reverse surface at a high speed (back grinding) and then eliminating the microcracks, generated in the grinding operation, by polishing or etching in order to improve the strength of the thin silicon. The back grinding is generally executed by rough grinding with a grindstone of #100 to #500 and finish grinding with a grindstone of #1500 to #3000. Also in case of forming a thin orifice plate of a thickness not exceeding 100 μm, it is common to remove the microcracks, generated in the grinding operation, by polishing or etching, since such microcracks deteriorate the strength. The polishing can be executed with ordinary alumina, silica or cerium oxide. Also the etching can be executed with fluoric acid, a mixture of fluoric acid and nitric acid, or an alkaline solution such as of sodium hydroxide, potassium hydroxide or tetramethyl ammonium hydrate. Such silicon thinning process is incorporated in a mass production apparatus commercialized for example by Okamoto Machinery Co. or Tokyo Oka Co.

[0160] Then the area around the discharge port is etched to cause the protective film 206 to protrude, thereby forming a projection 206a (108 in Fig. 18, Fig. 19G).

[0161] A projection 206a can be formed around the ink discharge port, by selecting a specified material for protecting the lateral wall of the recess formed on silicon in the thinning operation of the silicon substrate 201 and executing etching after the thinning operation. Such projection 206a avoids defective ink discharge resulting from the intrusion of the ink droplets deposited on the surface including the discharge ports and also avoids intrusion of the protective resin into the discharge port at the coating step of such protective resin on the discharge port surface.

[0162] For example, in case silicon nitride is employed as the protective material for the lateral wall of the recess, etching with fluoric acid or with a mixture of fluoric acid and nitric acid only leaves silicon nitride as a projection after the thinning operation. Also in case the lateral wall is protected by thermal oxidation of silicon, a projection 206a consisting of silicon oxide can be formed by etching with alkaline solution. The projection 206a preferably has a height of 0.5 to 10 μm, though it is related with the thickness of the protective film. An excessively large height of the projection 206a results in chipping, in the wiping operation with the blade in the actual use of the liquid discharge head.

[0163] Then the UV peelable tape is peeled off by UV irradiation (109 in Fig. 18, Fig. 19H), and the filling material 210 is removed by dissolving (210 in Fig. 18, Fig. 19I) whereby the aforementioned orifice plate 306 is completed. The UV irradiation was conducted with an apparatus UVM-200 supplied by Furukawa Denko Co., with an irradiation of 2 J/cm^2.

[0164] Then there is formed a film for protecting the surface including the ink discharge ports.

[0165] The protection of the surface including ink dis-

charge ports may be achieved either by forming a film of an ink-resistant material by the aforementioned methods after the thinning operation of silicon, or by coating an ink-resistant material on such surface after the liquid discharge head is prepared by adhering the orifice plate. Most preferably a water-repellent film is formed by coating fluorine resin or silicone resin to achieve ink-repellent property, whereby satisfactory recording can be realized since the surface containing the ink discharge ports is not wetted with ink.

[0166] Such fluorine resin can be Sitop supplied by Asahi Glass Co. or Sifel supplied by Shinetsu Chemical Industries Co. Such protective resin can be advantageously coated by a transfer method or a dispense method. In the transfer method, it is common to coat solution of the above-mentioned resin by a solvent coating method such as spin coating or bar coating on a resin or rubber sheet and transferring such coated film by applying such sheet to the surface including the discharge ports. Also heat may be applied if the transfer is difficult.

[0167] The most advantageous resin is Sitop mentioned above. It can be advantageously diluted with CT-Solv 180 which is the solvent for such resin to a concentration of 1 to 5 wt-%, then formed into a thin film by spin coating on a silicon wafer adhered with a silicon rubber sheet and is transferred in this state.

[0168] Finally a liquid discharge head is prepared by adjoining the orifice plate 216, prepared in the above-described steps, to a separately prepared head main body, formed by adjoining an element substrate and a top plate.

[0169] The filling material 210 may also be removed after the adjoining the orifice plate to the head main body.

[0170] Such producing method allows to easily avoid chipping in the grinding operation or intrusion of the grinding material in the penetrating holes in the polishing operation, without particular control in the thinning step of the substrate, thereby providing a liquid discharge head with stable liquid discharging operation.

[Liquid discharge recording apparatus]

[0171] Fig. 15 is a perspective view showing an ink jet recording apparatus, as an example of the liquid discharge recording apparatus, in which mounted is a liquid discharge head produced by the aforementioned method. A head cartridge 601 mounted in the ink jet recording apparatus 600 shown in Fig. 1 is provided with a liquid discharge head, produced by any of the foregoing methods, and a liquid container containing liquid to be supplied to such liquid discharge head. As shown in Fig. 15, the head cartridge 601 is mounted on a carriage 506 engaging with a spiral groove 606 of a lead screw 605, which is rotated through transmission gears 603, 604 by forward or reverse rotation of a driving motor 602. The head cartridge 601, together with the carriage 607, is reciprocated in directions a and b, along a guide 608, by the rotation of the driving motor 602. The ink jet recording apparatus 600 is also provided with recording medium conveying means (not shown) for conveying a printing sheet P, constituting a recording medium for receiving the liquid discharged from the head cartridge 601. A pressing plate 610, for pressing the printing sheet P which is conveyed on a platen 609 by the conveying means, presses the printing sheet P toward the platen 609 along the moving direction of the carriage 607.

[0172] In the vicinity of an end of the lead screw 605, there are provided photocouplers 611, 612, constituting home position detection means for detecting the presence of a lever 607a of the carriage 607 in the region of the photocouplers 611, 612 thereby switching the rotating direction of the driving motor 602. In the vicinity of an end of the platen 609, there is provided a support member 613 for supporting a cap member 614, which covers the front face, having the discharge ports, of the head cartridge 601. There is also provided ink suction means 615 for sucking ink, discharged by idle emission from the head cartridge 601 and collected in the cap member 614. The ink suction means 615 executes suction recovery of the head cartridge 601 through a port of the cap member 614.

[0173] The ink jet recording apparatus 600 is provided with a main body supporting member 619, on which a movable member 618 is supported movably in the front-rear direction, namely in a direction perpendicular to the moving direction of the carriage 607. The movable member 618 supports a cleaning blade 617. The cleaning blade 617 is not limited to the illustrate form but can assume any known form. Also a lever 620 is provided for starting the sucking operation at the suction recovery by the ink suction means 615, and is moved by the movement of a cam 621 engaging with the carriage 607, whereby the transmission of the driving force of the driving motor 602 is controlled through known transmission means such as a clutch. An ink jet recording control unit, for sending signals to the heat generating members provided in the head cartridge 601 and controlling the above-mentioned mechanisms is provided in the main body of the ink jet recording apparatus and is not illustrated in Fig. 15. The ink jet recording control unit is provided with drive signal supply means for supplying drive signals for causing the liquid discharge head to discharge the liquid.

[0174] The ink jet recording apparatus 600 of the above-described configuration executes recording on the printing sheet P which is conveyed on the platen 609 by the aforementioned recording medium conveying means, by executing reciprocating motion of the head cartridge 601 over the entire width of the printing sheet P.

[0175] As explained in the foregoing, in case of employing a silicon-containing material, same as that of the head main body, in the orifice plate, it is possible to realize a liquid discharge head of an elongated size with high reliability, by forming recesses by etching on the surface of a substrate consisting of such silicon-containing material in the preparation of the orifice plate and thinning such substrate from the reverse side thereof, thereby obtaining an orifice plate with plural discharge ports from

such substrate. Also a protective film constituting the internal wall of the discharge port is made to protrude from the surface of the discharge ports, whereby dispensed with is a cleaning operation of the area around the nozzle by wiping with a blade, so that there can be simplified the structure of the main body of the liquid discharge recording apparatus utilizing the liquid discharge head and the control sequence therefor. Further, the substrate for forming the orifice plate can be reinforced with a frame member whereby plural head main bodies can be adjoined to such orifice plate. Thus there is realized a producing method for the liquid discharge head, in which the orifice plate can include not only a nozzle array but also plural nozzle arrays with mutual alignment. As a result, there can be produced a liquid discharge head of excellent performance with a reduced cost.

Claims

1. A method for collectively producing plural silicon plates by forming plural functional units on a silicon wafer and dividing the silicon wafer for each functional unit, comprising:

    a step of forming, by dry etching, a plate dividing pattern corresponding to an external shape of each silicon plate on a first surface of the silicon wafer;
    a step of dividing the silicon wafer by thinning the silicon wafer from a reverse surface opposite to the first surface at least to the plate dividing pattern; and
    a step of providing each silicon plate with a through hole,

    wherein a through hole formation portion and the plate dividing pattern are simultaneously etched during the step of dry etching.

2. The producing method according to claim 1, wherein the step of thinning the silicon wafer is executed by reducing the thickness of the silicon wafer from the reverse surface thereof by a process selected from the group consisting of grinding, polishing, and etching.

3. The producing method according to claim 1, further comprising, before the step of dividing the silicon wafer, a step of providing a tape on the surface of the silicon wafer, in order to maintain the strength of the silicon wafer during any subsequent grinding or polishing thereof.

4. The producing method according to claim 3, further comprising, after the step of dividing the silicon wafer, a step of peeling off the tape.

5. The producing method according to claim 3, further comprising, after the step of dividing the silicon wafer, a step of conveying the silicon plate.

6. The producing method according to claim 5, wherein the silicon plate is stored during the step of conveying the silicon plate.

7. The producing method according to claim 1, wherein the plate dividing pattern is formed excluding an external periphery of the wafer.

Patentansprüche

1. Verfahren zur kollektiven Herstellung einer Vielzahl von Siliciumplättchen durch Bilden einer Vielzahl von funktionellen Einheiten auf einer Silicium-Halbleiterscheibe und Teilen der Silicium-Halbleiterscheibe für jede funktionelle Einheit, wobei das Verfahren umfasst:

    einen Schritt des Bildens eines die Plättchen teilenden Musters entsprechend einer äußeren Form jedes Siliciumplättchens durch Trockenätzen auf einer ersten Oberfläche der Silicium-Halbleiterscheibe;
    einen Schritt des Teilens der Silicium-Halbleiterscheibe durch Dünnen der Silicium-Halbleiterscheibe von einer rückwärtigen Oberfläche gegenüber der ersten Oberfläche bis mindestens zu dem die Plättchen teilenden Muster; und
    einen Schritt des Versehens jedes Siliciumplättchens mit einem durchgehenden Loch,

    wobei der Bildungsabschnitt für das durchgehende Loch und das die Plättchen teilende Muster simultan während des Schrittes des Trockenätzens geätzt werden.

2. Das Herstellungsverfahren nach Anspruch 1, wobei der Schritt des Dünnens der Silicium-Halbleiterscheibe durch Verringern der Dicke der Silicium-Halbleiterscheibe von ihrer rückwärtigen Oberfläche durch ein Verfahren ausgeführt wird, das aus der Gruppe ausgewählt wurde, die aus Schleifen, Polieren und Ätzen besteht.

3. Das Herstellungsverfahren nach Anspruch 1, welches ferner vor dem Schritt des Teilens der Silicium-Halbleiterscheibe einen Schritt zum Bereitstellen eines Bandes auf der Oberfläche der Silicium-Halbleiterscheibe umfasst, um die Festigkeit der Silicium-Halbleiterscheibe während jedem nachfolgenden Schleifen oder Polieren davon aufrecht zu erhalten.

4. Das Herstellungsverfahren nach Anspruch 3, wel-

ches ferner nach dem Schritt des Teilens der Silicium-Halbleiterscheibe einen Schritt des Abziehens des Bandes umfasst.

5. Das Herstellungsverfahren nach Anspruch 3, welches ferner nach dem Schritt des Teilens der Silicium-Halbleiterscheibe einen Schritt des Beförderns der Siliciumplättchen umfasst.

6. Das Herstellungsverfahren nach Anspruch 5, wobei das Siliciumplättchen während des Schrittes des Beförderns des Siliciumplättchens aufbewahrt wird.

7. Das Herstellungsverfahren nach Anspruch 1, wobei das die Plättchen teilende Muster ausschließlich eines äußeren Umfangs der Halbleiterscheibe gebildet wird.

Revendications

1. Procédé pour produire ensemble plusieurs plaques de silicium en formant plusieurs unités fonctionnelles sur une tranche de silicium et en divisant la tranche de silicium pour chaque unité fonctionnelle, comprenant :

    une étape de formation, par attaque à sec, d'un motif de division en plaques correspondant à une forme extérieure de chaque plaque de silicium sur une première surface de la tranche de silicium ;
    une étape de division de la tranche de silicium par amincissement de la tranche de silicium depuis une surface inverse opposée à la première surface au moins jusqu'au motif de division en plaques ; et
    une étape de réalisation d'un trou traversant dans chaque plaque de silicium,

    dans lequel une partie de formation d'un trou traversant et le motif de division en plaques sont gravés simultanément pendant l'étape de gravure à sec.

2. Procédé de production selon la revendication 1, dans lequel l'étape d'amincissement de la tranche de silicium est exécutée en réduisant l'épaisseur de la tranche de silicium depuis sa surface inverse par un processus choisi dans le groupe constitué d'un meulage, d'un polissage et d'une gravure.

3. Procédé de production selon la revendication 1, comprenant en outre, avant l'étape de division de la tranche de silicium, une étape d'application d'un ruban sur la surface de la tranche de silicium, afin de maintenir la solidité de la tranche de silicium pendant tout meulage ou polissage subséquent de celle-ci.

4. Procédé de production selon la revendication 3, comprenant en outre, après l'étape de division de la tranche de silicium, une étape d'enlèvement du ruban par pelage.

5. Procédé de production selon la revendication 3, comprenant en outre, après l'étape de division de la tranche de silicium, une étape de transport de la plaque de silicium.

6. Procédé de production selon la revendication 5, dans lequel la plaque de silicium est stockée pendant l'étape de transport de la plaque de silicium.

7. Procédé de production selon la revendication 1, dans lequel le motif de division en plaques est formé à l'exclusion d'une périphérie extérieure de la tranche.

FIG. 1

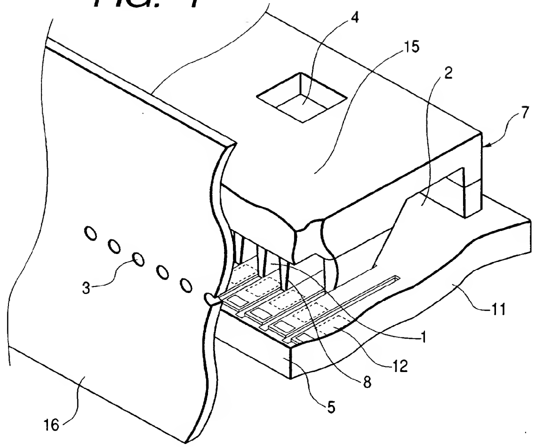


FIG. 2

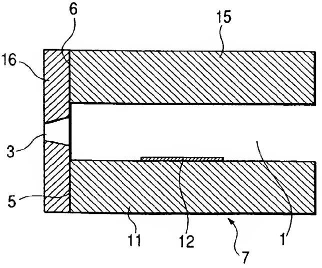


FIG. 3

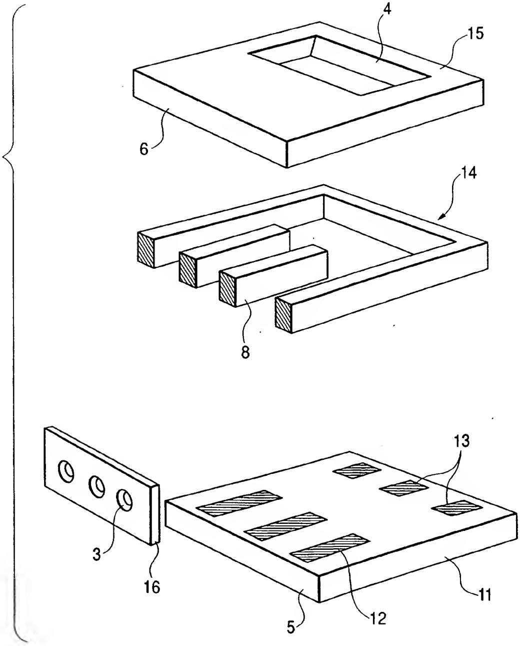


FIG. 4A1

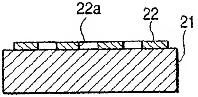


FIG. 4B

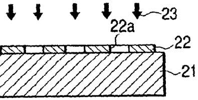


FIG. 4C1

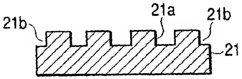


FIG. 4D1

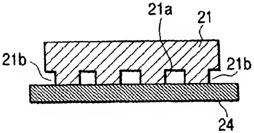


FIG. 4E1

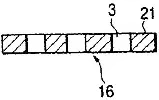


FIG. 4A2

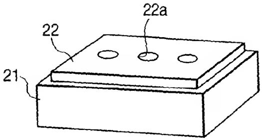


FIG. 4C2

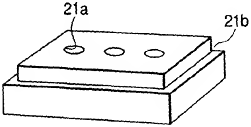


FIG. 4D2

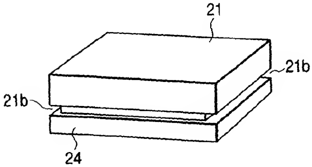


FIG. 4E2

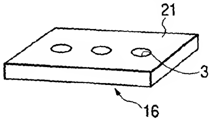


FIG. 5

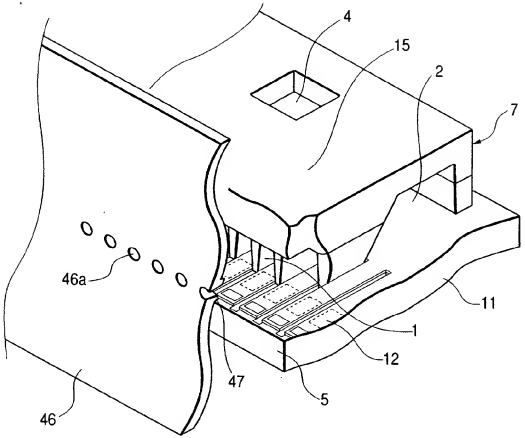


FIG. 6

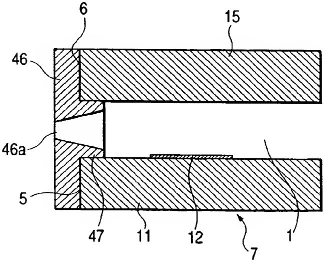


FIG. 7

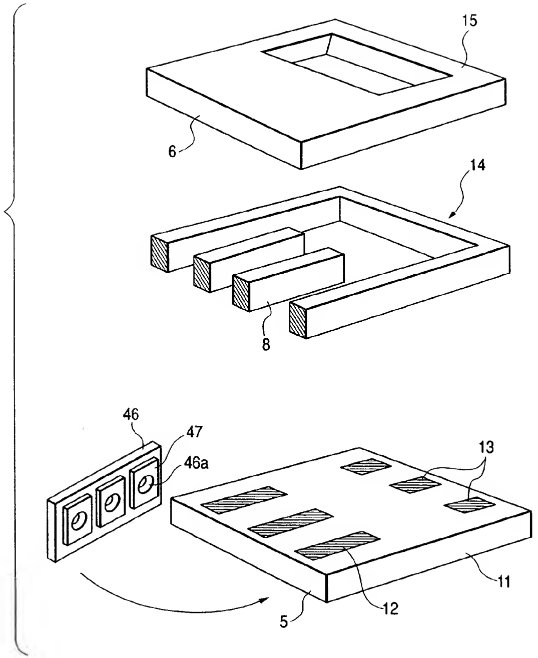


FIG. 8A1

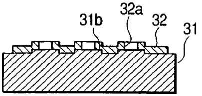


FIG. 8B

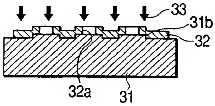


FIG. 8C1

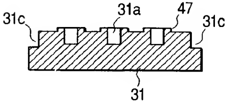


FIG. 8D1

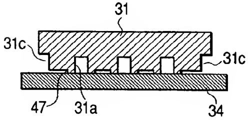


FIG. 8E1

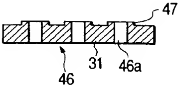


FIG. 8A2

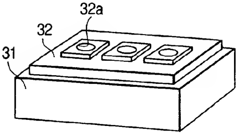


FIG. 8C2

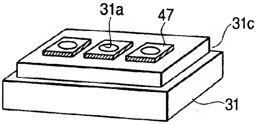


FIG. 8D2

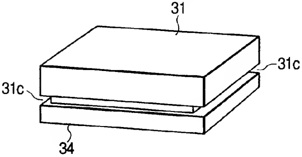


FIG. 8E2

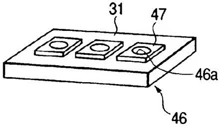


FIG. 9A

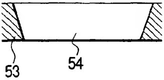


FIG. 9B

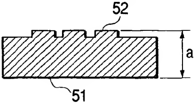


FIG. 9C

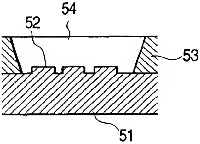


FIG. 9D

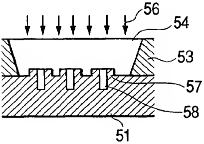


FIG. 9E

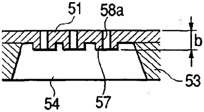


FIG. 9F

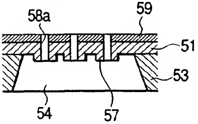


FIG. 9G

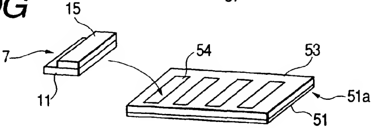


FIG. 10

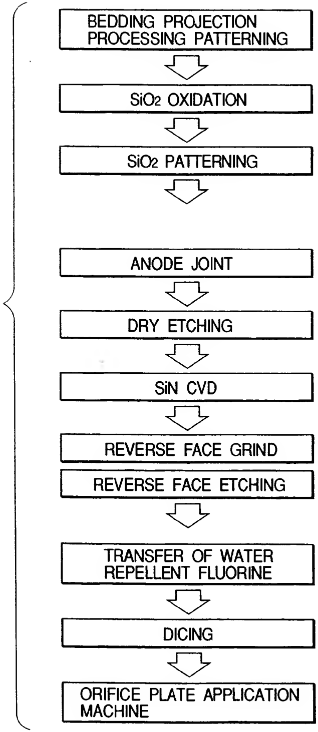

BEDDING PROJECTION PROCESSING PATTERNING
SiO2 OXIDATION
SiO2 PATTERNING
ANODE JOINT
DRY ETCHING
SiN CVD
REVERSE FACE GRIND
REVERSE FACE ETCHING
TRANSFER OF WATER REPELLENT FLUORINE
DICING
ORIFICE PLATE APPLICATION MACHINE

FIG. 11

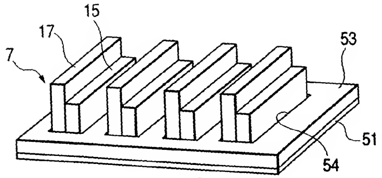


FIG. 12A1

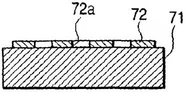


FIG. 12A2

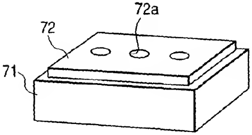


FIG. 12B

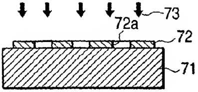


FIG. 12C1

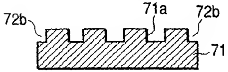


FIG. 12C2

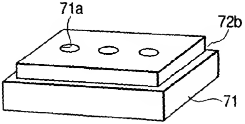


FIG. 12D

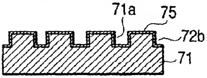


FIG. 12E1

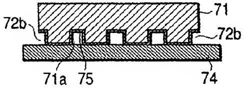


FIG. 12E2

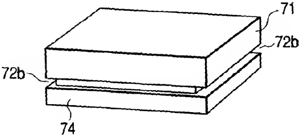


FIG. 12F

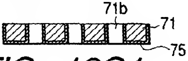


FIG. 12G1

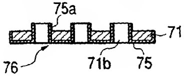


FIG. 12G2

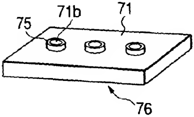
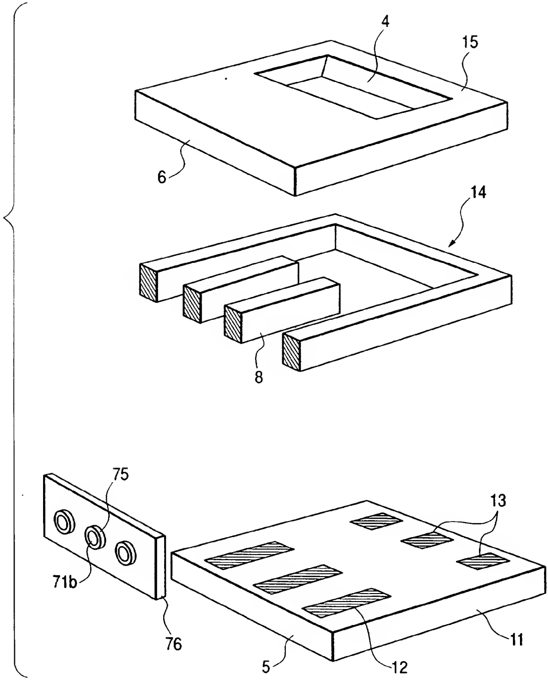


FIG. 13



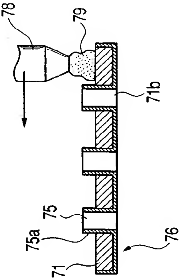


FIG. 14A1

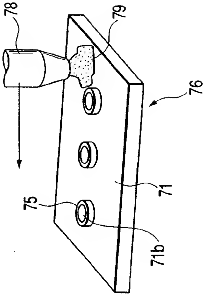


FIG. 14A2

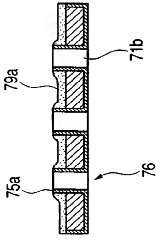


FIG. 14B1

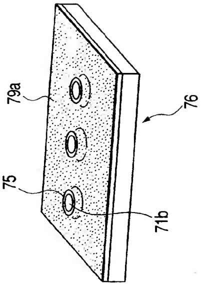
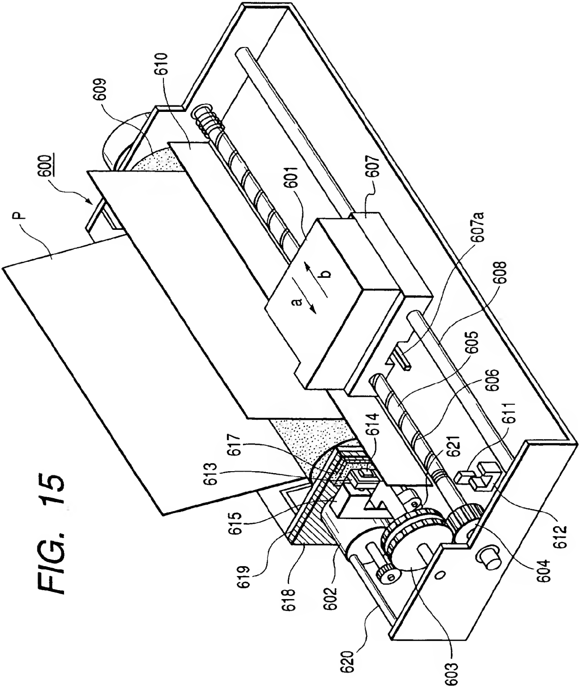


FIG. 14B2

FIG. 15


P
600
609
610
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607
607a
608
605
606
611
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602
618
619
615
613
617
614
621
a
b

FIG. 16A

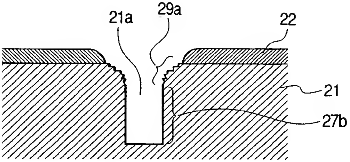

FIG. 16B

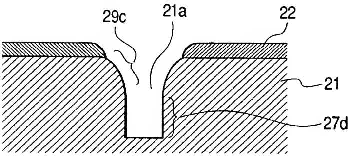

FIG. 16C

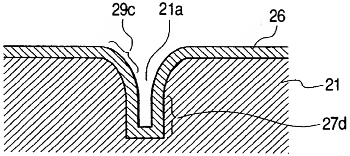

FIG. 16D

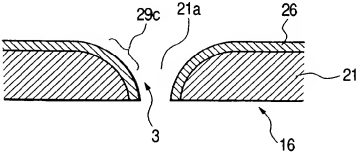

FIG. 17A

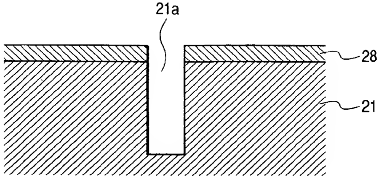

FIG. 17B

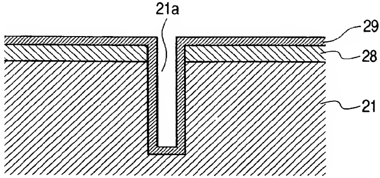

FIG. 17C

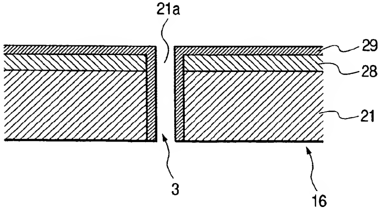

FIG. 18

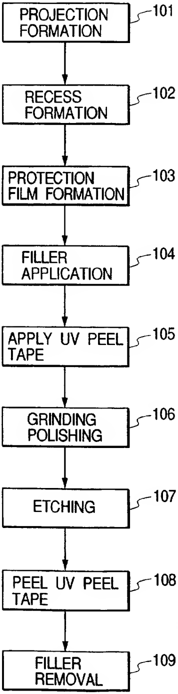

FIG. 19A

FIG. 19B

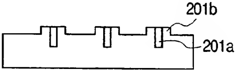

FIG. 19C

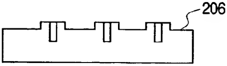

FIG. 19D

FIG. 19E

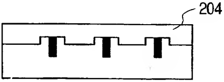

FIG. 19F

FIG. 19G

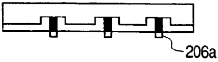

FIG. 19H

FIG. 19I

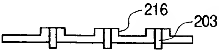

FIG. 20

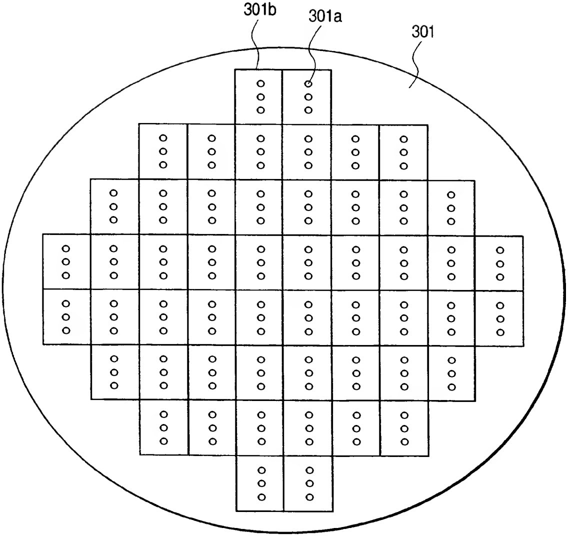

FIG. 21A

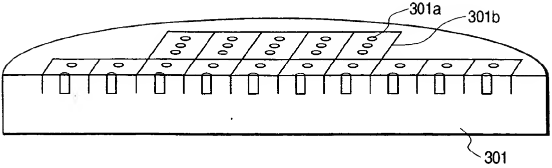

FIG. 21B

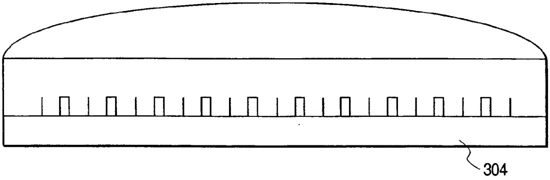

FIG. 21C

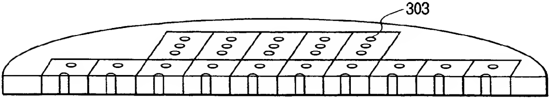

FIG. 21D

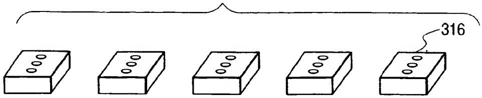

FIG. 22A

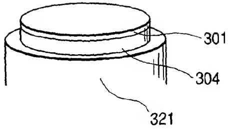

FIG. 22B

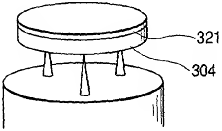

FIG. 22C

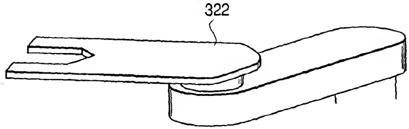

FIG. 22D

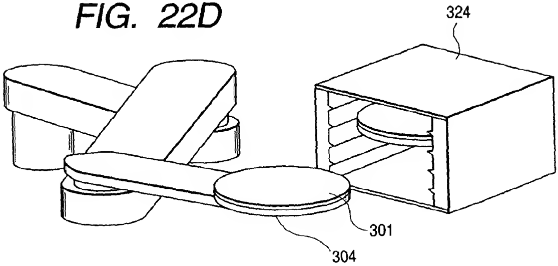

FIG. 23

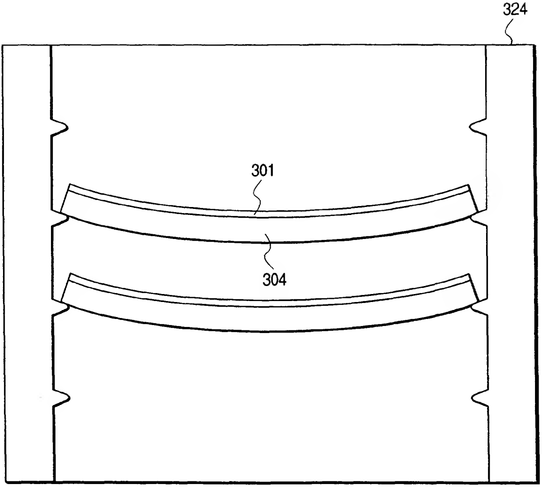

FIG. 24A

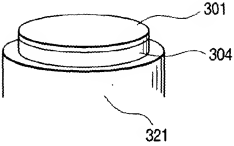

FIG. 24B

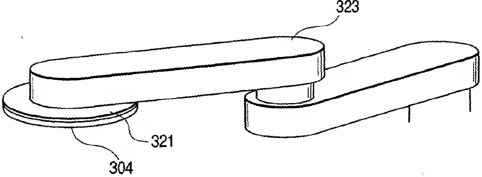

FIG. 24C